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12.3.2

Draft Remedial Investigation and Focused Feasibility Study

Quendall Terminals Property
Renton, Washington

Prepared by:

The RETEC Group, Inc.
1011 S.W. Klickitat Way, Suite 207
Seattle, WA 98134-1162

ThermoRetec Project Number: JAGCO-02438-770

Prepared for:

Vulcan Northwest, Inc.
505 Fifth Avenue South, Suite 900
Seattle, WA 98104

March 27, 2002

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March 27, 2002

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Aspect Consulting, LLC

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List of Acronyms and Abbreviations

AET	Apparent effects threshold
ARAR	Applicable or relevant and appropriate requirement
AWQC	Ambient water quality criteria
CAP	Cleanup Action Plan
City	City of Renton
CoC	Constituent of concern
cPAH	Carcinogenic PAH
CSL	Cleanup screening level
DMMP	Dredged Materials Management Program
DNAPL	Dense, nonaqueous-phase liquid
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
EEC	Extreme effects concentration
EIS	Environmental impact statement
EPA	U.S. Environmental Protection Agency
GAC	Granular activated carbon
HPAH	High molecular weight PAH
LAET	Lowest AET
LPAH	Low molecular weight PAH
MEC	Median effects concentration
MTCA	Model Toxics Control Act
NAPL	Nonaqueous-phase liquid
PAET	Probable AET
PAH	Polycyclic aromatic hydrocarbon
PCP	Pentachlorophenol
PPA	Prospective Purchaser Agreement
PQL	Practical quantification limit
RAO	Remedial action objective
RCRA	Resource Conservation and Recovery Act
RETEC	Remediation Technologies, Inc.

List of Acronyms and Abbreviations

RI/FFS	Remedial investigation and focused feasibility study
RPD	Redox potential discontinuity
SEPA	State Environmental Policy Act
SMS	Sediment Management Standards
SQS	Sediment quality standards
SVE	Soil vapor extraction
TEC	Threshold effects concentration
WCC	Woodward-Clyde Consultants, Inc.

Executive Summary

This document presents the Remedial Investigation and Focused Feasibility Study (RI/FFS) for the Quendall Terminals property, a 23-acre parcel located on the eastern shore of Lake Washington in Renton, Washington. The property has had various industrial uses since the early 1900s and has been the subject of an extensive series of environmental investigations starting in 1971. These investigations have indicated that the property is heavily contaminated from coal tar refining activities that occurred there between 1917 and 1969. The contaminated areas include onsite soil and groundwater, areas of dense nonaqueous-phase liquid (DNAPL), and the Lake Washington shoreline and sediments. Primary contaminants found at the site are PAHs, benzene, DNAPL, and wood waste. The Washington State Department of Ecology (Ecology) has assigned the site a hazard ranking of 1.

Since the early 1970s, various parties have attempted to purchase, clean up, and redevelop the Quendall Terminals property; however, each of these efforts has proved unsuccessful because of the extensive contamination at the site, difficulties in addressing the environmental liabilities posed by the site, and the extensive infrastructure and geotechnical improvements required for site redevelopment. In light of certain unique opportunities offered by the location, size, and nature of the site, the City of Renton (City) recognized that the Quendall Terminals property could become an important and valuable asset to the citizens and a major revenue source to the City if cleaned up and redeveloped. As a result, the City has continued to work to develop an effective plan to restore the Quendall Terminals property to beneficial use for the community.

First, the Quendall Terminals property serves as a cornerstone for redevelopment of a much larger area that could include three other adjacent parcels offering redevelopment opportunities (i.e., the J.H. Baxter and Company property located to the north, the Barbee Mills property located to the south, and the Pan Abode property located to the southeast). In addition, the Quendall Terminals property and adjacent properties include unique shoreline and nearshore habitat that contrasts sharply with the otherwise heavily developed nature of Lake Washington. This relatively undeveloped shoreline offers opportunities for enhancing natural habitat and permanent public shoreline access.

To take advantage of these opportunities, the City intends to enter into the Prospective Purchaser Agreement (PPA) process with Ecology to facilitate the remediation and redevelopment of the Quendall Terminals property. Under the proposed plan, the City would purchase the site from the current owners and remediate the site using funding from city, state, federal, and private sources. If the City is successful in managing the environmental risk at Quendall Terminals, future plans include providing permanent shoreline access through a waterfront park and selling the remaining upland portions of Quendall Terminals to a private developer for a mixed-use development.

The successful cleanup and redevelopment of the Quendall Terminals property will provide benefits to the citizens of the State of Washington and the City. These benefits include management of environmental risk at a site situated on a shoreline of statewide significance that has a hazard ranking of 1 on Ecology's Hazardous Sites List; creation of approximately 0.25 mile of permanent shoreline access for the public, with additional adjoining shoreline access possible at the adjacent sites; shoreline and lake-bottom habitat restoration that will benefit salmonids and other wildlife (including endangered species); and both direct and indirect economic benefits to the City and State.

This RI/FFS provides necessary documentation to support the PPA. It summarizes existing information regarding site uses, characteristics, and conditions as derived from the extensive previous site investigations. It also reviews the potential human health and environmental risks posed by the site, the qualitative and numerical remedial action objectives used to determine site cleanup requirements, and the remedial technologies identified to implement the cleanup goals.

Based on the information compiled and analyzed in the RI/FFS, the following remedial actions were selected to address contamination at the site:

- To address contaminants in soil, the entire surface of the site will be covered by a 3-ft-thick clean soil cap or pavement, buildings, or other structures placed on the soil surface that would similarly prevent exposure to residual contaminants in soil. DNAPL-affected soil will also be excavated from selected areas of the site. This soil will be treated and returned to the excavations.

To address contaminants in sediments, the sediments and nearshore soil from several areas will be dredged and treated. These excavated areas will be backfilled with treated or clean materials. These areas include the vicinity of the T-dock where sediments are affected by PAH compounds and the nearshore area affected by a DNAPL seep. In addition, sediments containing more than 50 percent wood waste will be dredged. Because this action will restore the lake bottom to its approximate original contours, these areas will not be backfilled. Certain other sediments containing less than 50 percent wood waste may be covered with a cap of 1-ft maximum thickness, consisting of imported clean fill and/or treated sediments and soils. The extent of this cap will be determined based on toxicity testing that is currently scheduled for summer 2000.

Executive Summary

Requirements for compliance sampling and ongoing monitoring and maintenance activities are also specified in the preferred remedial alternative described here.

1 Introduction

1.1 Scope and Purpose

This Feasibility Study (FS) is intended to address environmental contamination problems associated with the Quendall Terminals property. The objective of this report is to assess the nature and extent of chemical impacts to the site and to present a protective remedial alternative for the site that satisfies Ecology's evaluation criteria provided in MTCA (WAC 173-340-360).

This document summarizes existing information regarding site uses, characteristics, and conditions as derived from previous site investigations and includes a description of more recent investigations. It also reviews the potential human health and environmental risks posed by the site, the qualitative and numerical remedial action objectives used to determine site cleanup requirements, and the remedial technologies and alternatives identified to be implemented to satisfy the remedial action objectives.

1.2 Project Background

Since the early 1970s, various parties have attempted to purchase, clean up, and redevelop the Quendall Terminals property; however, each of these efforts has proved unsuccessful for at least the following three reasons:

- The extensive contamination at the site,
- An inability of the parties to reach agreement given the undefined liabilities posed by environmental remediation, and
- The need for extensive transportation infrastructure and geotechnical improvements in connection with redevelopment.

In light of unique opportunities offered by the location, size, and nature of the site, the City of Renton (City) recognized that the Quendall Terminals property could become an important and valuable asset to the citizens and a major revenue source to the City if cleaned up and redeveloped. As a result, the City has continued to work to develop an effective plan to restore the Quendall Terminals property to beneficial use for the community.

The Quendall Terminals property is located at the center of three other adjacent parcels offering redevelopment opportunities (Figure 1-1; J.H. Baxter and Company property to the north, Barbee Mills property to the south, and Pan Abode property to the southeast). Thus, the Quendall Terminals property serves as a cornerstone for redevelopment of a much larger area. In addition, the Quendall Terminals property and adjacent properties include unique shoreline and nearshore habitat that contrast sharply with the otherwise heavily developed nature of Lake Washington. This relatively undeveloped shoreline offers opportunities for enhancing natural habitat and permanent public shoreline access.

To take advantage of these opportunities, the City intends to enter into the Prospective Purchaser Agreement (PPA) process with Ecology to facilitate the remediation and redevelopment of the Quendall Terminals property. Under the proposed plan, the City would purchase the site from the current owners and remediate the site using funding from city, state, federal, and private sources. If the City is successful in managing the environmental risk at Quendall Terminals, future plans include providing permanent shoreline access through a waterfront park along the entire adjacent shoreline area and selling the remaining upland portions of Quendall Terminals to a private developer for a mixed-use development.

The successful cleanup and redevelopment of the Quendall Terminals property will provide benefits to the citizens of the State of Washington and the City. Foremost, the cleanup would yield management of environmental risk at a site that has a hazard ranking of 1 on Ecology's Hazardous Sites List and is situated on a shoreline of statewide significance. Second, the cleanup and redevelopment would lead to the creation of approximately 0.25 miles of permanent shoreline access for the public, with additional adjoining shoreline access possible at the adjacent sites. This access would yield benefits to the region for the indefinite future. In addition, shoreline and lake-bottom habitat restoration will benefit salmonids and other wildlife and may contribute to the recovery of endangered species.

The economic benefits to the City and State governments include additional revenue from property taxes on any improvements, sales tax revenue from retail sales and hotels, and transportation taxes based on the number of full-time workers. In addition to the direct tax benefits, creation of a mixed-use development will provide economic benefit to the citizens through increased employment opportunities, increased business to local restaurants and shops, and increased property value of local residences resulting from improvements in the area.

[redacted]. After the property is purchased, the City will perform the cleanup and will comply with MTCA by performing the actions described in the attachments to the PPA, which will include the Cleanup Action Plan (CAP) derived based on information presented in this FS.

1.3 Site Background and History

The 23-acre Quendall Terminals property is located on the southeastern shore of Lake Washington in Renton, Washington. The site is heavily contaminated from the coal tar refining that occurred there from 1917 to 1969. The contaminated areas include onsite soils, onsite groundwater, areas of dense nonaqueous-phase liquid (DNAPL), the Lake Washington shoreline, and Lake Washington sediments. Contaminants found onsite primarily consist of polycyclic aromatic hydrocarbons (PAH) compounds, benzene, and wood waste. A local lumber company is currently using the site as a log-sorting yard.

1.3.1 Site Use History

The Quendall Terminals property began as a homestead conveyed to Jeremiah Sullivan in 1873. It was conveyed to James Colman in 1875 and then to Peter Reilly by deed in 1916. Prior to the lowering of Lake Washington in 1916 to build the Lake Washington Ship Canal, the site consisted of a headland and the swampy May Creek delta (RETEC 1996a).

The site has historically been used for industrial purposes. When the lake was lowered approximately 8 feet, the May Creek delta was exposed and the land area of the waterfront parcel increased. In 1917, the Reilly family established the Republic Creosoting Company, which became Reilly Tar and Chemical Corporation in 1956. Creosote was manufactured onsite until 1969 (RETEC 1996a).

The original bed of May Creek ran east-west across the Quendall Terminals property. Between 1920 and 1936, the original channel was partially filled, and the creek was rerouted to a location roughly at the midpoint of the Barbee Mill property. Between 1936 and 1956, the creek was moved farther to the south a number of times.

Coal Tar Refining Activities

The facility refined and processed coal tar and oil-gas tar residues. The tars consisted of PAH compounds, phenolic compounds, light aromatic compounds (including benzene, toluene, and xylenes), and other organic compounds. The tar was purchased from various sources, including the Seattle Gas Company on Lake Union, and was shipped or barged to the site and pumped through transfer lines that ran along a former wharf and pipe trestle. The docks included the southern pier dock and the longer T-dock, which were used for offloading tankers and barges (RETEC 1996a). From the docks, the transfer lines ran to two 2 million-gallon storage tanks (tanks 23 and 26) located in the west central tank farm area, as shown on Figure 1-2. The tanks contained heating elements to keep the liquid warm, thus allowing it to be transferred to the still house, where the tars were refined to produce creosote and distillates (Hart Crowser 1997). Tar distillates were further refined to produce naphthalenes, xylenes, benzene, toluene mix, and other organic products. The products were then stored in onsite tanks until shipment (Roberts 1981).

Tanks 1 through 5, located just south of the still, were installed in 1916 to store creosote-related products. The two largest storage tanks, tanks 23 and 26, were installed in 1928 primarily to store the raw coal tar materials. Tanks 35, 36, 37, and 38 were constructed in 1956 and are located in the west-central area of the site. These tanks were also used to store creosote-related products.

Historic facility features were identified to locate areas of potential environmental impact caused by tar refining operations. Potential onsite sources of soil and groundwater contamination are listed below; these locations, with the exception of the "Saturday coke" disposal area, are shown on Figure 1-2 (RETEC 1996a).

- The still house
- The underground pipes in the still house
- Onsite disposal areas for waste pitches and "Saturday coke"
- The ends of the docks, where spills occurred, including a release in 1937 in which approximately 30,000 to 40,000 gallons of tar spilled into the lake off the end of the T-dock
- The flush box and sanitary sewer outfall
- Pitch bays (40 feet x 150 feet x 4 feet) constructed with concrete bottoms and wooden sides, used for cooling of pitches
- The old bed of May Creek, where tank cleaning residues were dumped
- Former sumps that received effluent from cooling lines and were sometimes contaminated with creosotes and tars
- Tanks 23, 26, 35, 36, 37, and 38, where creosote-related products and, later, petroleum products were stored.

Lease records for the Quendall Terminals property indicate that from 1946 to 1951, DNR-owned aquatic lands in front of the property were subleased to Kennydale Shipyards. An aerial photograph from this period shows approximately 50 barges stored in this area. This area has been used for log rafting operations since 1936.

Subsequent Site Uses

The site was used intermittently as a crude oil, waste oil, and diesel storage facility from 1969 until 1978. Tanks 35, 36, 37, and 38 were used regularly for this purpose during this period; Tanks 23 and 26 were used only once to store these products (Figure 1-2; Hart Crowser 1997). After 1983, the site was graded and raised with approximately 3 feet of fill material, including a soil and wood mixture (RETEC 1997a). Since 1977, the site has been used as a log sorting and storage yard, for firewood cutting, and for storage of in-water construction equipment. After 1977, no chemicals or petroleum products, other than what is used for operation of heavy equipment, are known to have been stored onsite. All structures associated with the refinery operations, except for the office building, have been removed from the property. Wood chips and bark are scattered across the property as a result of the logging operations (Hart Crowser 1997).

1.3.2 Adjacent and Surrounding Properties

J.H. Baxter—The J.H. Baxter property lies to the north of the Quendall Terminals property (Figure 1-1). The property was residential until 1955, when J.H. Baxter and Company constructed a wood treatment facility on the southern end of the property. The wood treatment facility operated on the site from 1955 to 1981. Pentachlorophenol (PCP) and creosote were used to treat poles, pilings, and railroad ties. A map of then-existing conditions at the Quendall Terminals property, drawn by J. Carson Bowler Architects in February 1972, shows a pipeline connecting the Reilly Tar and Chemical tank farm with the storage tanks located on the J.H. Baxter site. J.H. Baxter's 1970 and 1971 waste discharge permit documents indicate that creosote was purchased from Reilly Tar and Chemical. This suggests that the pipeline was used to transfer creosote or oils to the J.H. Baxter property for use in wood treating operations there. Since 1981, the J.H. Baxter property has been largely inactive, except for the storage of large piles of landscaping bark on the northern section of the property (RETEC 1996a, 1997a). The property was split into two, and Vulcan Northwest, Inc. (Vulcan) purchased both the properties in 2000. A PPA Consent Decree between Vulcan and Ecology has been entered for both the North and South Properties.

Barbee Mill—The Barbee Mill is located to the south of the Quendall Terminals (Figure 1-1), and has been used for timber and lumber activity since the turn of the century. In the early 1900s, a logging railway terminated at the property, where logs were transferred from railcars to barges.

From 1943 to 1946, a shipyard called Barbee Marine Yards built wooden boats on the property. At this time, a lumber mill was established onsite to service the shipyard. After World War II, shipbuilding activity ceased, and the lumber mill became the primary land use (RETEC 1997a). Log rafting in Lake Washington is suspected to have deposited wood waste on nearshore sediment at the Barbee Mill property. In addition, historic activities at the Barbee Mill have resulted in potential arsenic impacts on the southwest corner of the Quendall Terminals property. The owners of the mill property are addressing the arsenic issues.

Pan Abode—The Pan Abode property is located southeast of the Quendall Terminals property and was owned by Reilly Tar and Chemical until 1957 (Figure 1-1). Pan Abode Cedar Homes, Inc., purchased the property in 1957 for use in manufacturing prefabricated cedar homes. Prior to this time, the property was undeveloped and there is no indication that Reilly Tar and Chemical used it in the tar refining process. Cedar homes are manufactured at the facility, and areas of the property are used for storing large boats and motor homes. Environmental investigations at the property indicated there are no environmental impacts that exceed MTCA criteria (RETEC, 1997). Vulcan purchased the property in 1999.

1.4 Summary of Previous Investigations

Environmental and/or geotechnical studies have been performed on the Quendall Terminals property since 1971, when Quendall Terminals purchased the site from Reilly Tar and Chemical. Monitoring wells, boreholes, test pits, and temporary well points have been installed onsite and offsite. A brief summary of the previous investigations based on the descriptions provided by Remediation Technologies, Inc. (RETEC), and Hart Crowser (RETEC 1996a,b, 1997a,b,c; Hart Crowser 1997) is presented below. The Final Remedial Investigation Report for the Quendall Terminals Property was submitted to Ecology in March 1997. A chronological list of previous investigations is presented in Table 1-1. Onsite locations of all available soil samples, borings, groundwater samples and sediment samples are shown in Figure 1-3. All available analytical data compiled are presented in Appendices A, B, and C. Additional investigation activities performed in 2001 to support this FS are summarized in this section with additional details provided in Appendix D.

Twelker and Associates, Inc.

Between 1971 and 1977, Twelker and Associates, Inc., conducted site investigations in support of site development. These studies were mainly geotechnical and included 15 onsite soil borings (B-1 through B-15) and 17 offshore borings (logs A through O) (Twelker 1971, as cited by Hart Crowser 1997).

Shannon and Wilson, Inc.

In 1975, Shannon and Wilson, Inc., conducted a soil investigation that included borings along May Creek and near Barbee Mill and Pan Abode (RETEC 1996a, 1997b).

CH2M Hill, Inc.

Beginning in 1974, CH2M Hill conducted investigations on the site related to geotechnical characterization (CH2M Hill 1978) and environmental impact assessment for a master planned development (CH2M Hill 1981). Lake current and water quality studies (CH2M Hill 1977, 1979, as cited by Hart Crowser 1997) were included in the environmental impact assessment.

U.S. Environmental Agency

In 1983, the EPA inspected the site, focusing on sediment contamination. The inspection included visual observations made during a self-contained underwater breathing apparatus survey and sediment sampling for chemistry. Aquatic plants, fish, and invertebrates were surveyed. Evidence of free product in sediment was noted, and sediment cores were taken and analyzed for PAH contamination (U.S. EPA 1983, as cited by RETEC 1996a). Analytical results of the EPA inspection are included in Appendix C.

Woodward-Clyde Consultants, Inc.

Woodward-Clyde Consultants, Inc. (WCC) performed a soil and groundwater contamination investigation in 1983 (WCC 1983, as cited by Hart Crowser 1997). The consultants performed the following work:

- Drilled 18 soil borings to depths between 10 and 20 feet below ground surface
- Installed 4 trenches, measuring 250 feet long by 8 feet wide
- Installed 12 monitoring wells (BH-1 through BH-12)
- Collected 134 soil samples, which were screened for the presence of PAH using an absorbance screening technique
- Analyzed 6 soil samples for volatile aromatics, including benzene, toluene, and xylenes
- Analyzed 2 additional samples for priority volatile and semivolatile organic compounds
- Collected groundwater from 12 monitoring wells and analyzed samples for PAH, volatile aromatics, and field parameters (e.g., pH, alkalinity)
- Analyzed 5 additional groundwater samples for PCP using a screening method (WCC 1983, as cited by Hart Crowser 1997).

As part of the Consent Decree signed by Quendall Terminals and Ecology in 1988 (WCC 1990, 1991a, as cited by Hart Crowser 1997), WCC conducted the following additional work:

- Installed 11 additional monitoring wells (BH-17 through BH-23) at 7 locations (9 of the 12 wells installed in 1983 had been destroyed by log yard operations)
- Collected 42 soil samples from the 7 well locations and analyzed the samples for PAH, PCP, and dibenzofuran using EPA Method 625

- Conducted groundwater sampling quarterly (January 1989 and March 1990). Groundwater samples were analyzed for volatile and semivolatile organic compounds, metals, and field parameters (including nitrate, nitrite, sulfate, alkalinity, pH, and dissolved oxygen).

In 1990, WCC installed 6 additional wells at 4 locations (BH-24 through BH-27). A total of 16 soil samples collected from the 4 well locations were analyzed for semivolatile organic compounds using EPA Method 8270. In June 1991, groundwater was sampled from 6 wells and analyzed for volatile (EPA Method 8240) and semivolatile (EPA Method 8270) organic compounds (WCC 1990b, 1991a, as cited by Hart Crowser 1997). Analytical results of the WCC investigations for PAH, PCP, and metals are included in Appendices A and B.

WCC completed additional investigations in 1991 (WCC 1991b, 1992a, as cited by Hart Crowser 1997). The studies included the following:

- Investigated in situ bioremediation at the Quendall Terminals site by evaluating chemical and microbiological parameters (e.g., metals, major ions, nutrients, dissolved oxygen, chemical and biological oxygen demand, alkalinity, and microbial counts)
- Studied whether DNAPL present in several shallow groundwater monitoring wells on the Quendall Terminals site could be recovered efficiently (DNAPL was pumped out of wells BH-21A and BH-5, where product thickness of 1 to 6 feet had been observed)
- Conducted aquifer pump tests in wells BH-19, BH-25, and BAX-9 to estimate hydraulic properties, including transmissivity, hydraulic conductivity, and storage efficiency of the upper water bearing unit.

Washington State Department of Ecology

In 1991 and 1992, Ecology conducted a sediment investigation at the Quendall Terminals and J.H. Baxter properties. The investigations focused on shallow sediment (0 to 2 centimeters deep). Analyses were conducted for PAH compounds, PCP, PCBs, and heavy metals. In addition, bioassays and measurements of macroinvertebrate abundance were conducted (Ecology 1992b, as cited by RETEC 1996a). Analytical data from the sediment investigation are presented in Appendix C.

Hart Crowser

After the work described under the 1988 Consent Decree was completed, Ecology and Quendall Terminals entered into an Agreed Order in 1993 for an RI/FS at the site. The work to be performed included a supplemental remedial investigation, a risk assessment, and a feasibility study. Hart Crowser was hired to perform this work in 1995 and 1996, which included additional field investigations to further delineate the nature and extent of contamination. Hart Crowser's field activities are listed below:

- Excavated 9 test pits (TP-1 through TP-9)
- Drilled 9 soil borings (HC-1 through HC-8, and BH-28)
- Installed 1 monitoring well (BH-28)
- Sampled soil vapor flux at 4 locations (VP-1 through VP-4)
- Sampled and analyzed groundwater and free-phase product in December 1995
- Monitored water levels over 12-month period
- Sampled and analyzed groundwater discharge (WP-1 through WP-6) and Lake Washington surface water (SW-1 through SW-6).

The results of these investigations were presented in the Final Remedial Investigation for Quendall Terminals Uplands (Hart Crowser 1997). Analytical results are presented in Appendices A and B.

Remediation Technologies, Inc. (RETEC)

RETEC has conducted a number of environmental investigations on the property. In 1996, RETEC compiled and reviewed available sediment, soil, groundwater, storm water, surface water, and toxicity data from the Quendall Terminals, J.H. Baxter, and Pan Abode properties. RETEC subsequently published Summary of Existing Environmental Data and Data Gaps for the Jag Project Area (RETEC 1996b). Based on this review of available data, the following tasks were identified as necessary for completion of a feasibility study: shallow sediment sampling, wood waste surveying, wood waste characterization, shoreline core sampling to identify locations of NAPL seeps to sediment, and supplemental chemistry (RETEC 1996b). These tasks were completed, and RETEC presented the results in its Draft Sediment Quality Memorandum (1997b). In summary, the sediment investigation included:

- Bathymetric survey of the lake bottom
- Delineation of lake bottom wood debris
- Coring of subsurface sediment along the Quendall Terminals shoreline and analysis of sediment (EPA Method 8020 and/ or EPA 8260)
- Biological testing of sediments

- Elutriate testing of Quendall Terminals sediment
- Sampling of sediment infauna and macrofauna.

In 1997, RETEC submitted to Ecology a review of the upland soil conditions in the Upland Constituents Memorandum (RETEC 1997c). Upland soil conditions were assessed by reviewing field and laboratory analytical data, as well as all available field observations. The distribution of affected soil within the project area was outlined, and areas of the site were delineated according to the extent and type of contamination. Affected soil volumes for various cleanup criteria were also calculated. Analytical data from the RETEC investigations are included in Appendices A, B, and C.

Exponent

Exponent conducted an assessment of the sediments at the Quendall Terminals Property. The objective of this assessment was to identify whether deleterious effects on benthic organisms are associated with the 'gray zone' sediments that had been identified in previous site investigations based on the criteria of a wood waste content less than 50 percent and an observed redox potential discontinuity of less than 0.8 cm.

ThermoRetec Consulting Corporation (RETEC)

In order to address issues associated with Ecology comments on the Exponent draft Remedial Investigation and Focused Feasibility Study (Exponent, 1999) and the draft Cleanup Action Plan (Exponent, 1999), ThermoRetec developed a mudline groundwater sampling program. The investigation included groundwater sampling 10 shoreline wells and 18 wellpoint locations in Lake Washington.

Mudline conditions were evaluated through installation and sampling of in-water wellpoints and upland shoreline wells. Wellpoint locations were determined using a groundwater flow model to predict transport from upland shoreline wells. A total of 20 wellpoints were installed along transects in-line with existing upland shoreline wells. Existing shallow aquifer shoreline wells were present at each of the five upland locations. Because co-located deep aquifer wells were only present at three of the shoreline well locations, it was necessary to install two additional deep aquifer wells.

Water samples were collected at each of the 10 upland wells and 18 wellpoints using low-flow techniques. Samples could not be obtained from two of the wellpoint locations. Samples were analyzed for PAHs and BTEX compounds using the SIM-Pro method to achieve low detection limits as requested by Ecology. Results of the sampling are summarized below. Methods and results are described in detail in Appendix D.

- The nearshore PAH seep near Quendall Pond may be larger than anticipated, as shown by high levels of contamination detected in well points WP-19A and WP-19B.
- Well point WP-20B, approximately 250 feet from shore, contains high concentrations of benzene and naphthalene. This unexpected contamination could be caused by a NAPL source located in the sediments near the wellpoint. Alternatively, contamination in the deep groundwater could be more extensive than initially estimated.
- NAPL may be present within the sand/gravel layer as shown by high concentrations observed in the deep aquifer at well BH-20B. Vertical migration of DNAPL to this lower layer is a serious concern that was not evaluated in previous investigations.
- The North Sump NAPL plume does not appear to be impacting surface water. Contamination was not detected in the in any of the three well points offshore from the North Sump area: WP-18A, WP-18B, of WP-18C.
- Carcinogenic PAH exceedances were found in only two shoreline wells (BH-20A and BH-21A) and one wellpoint (WP-21C). Previous investigations suggested a potentially larger carcinogenic PAH concern.

A geoprobe investigation focusing on the area within 200 feet of the shoreline was conducted to further define the extent of NAPL plumes and groundwater quality. Boring locations were chosen where data gaps existed and were usually 50 feet from another sampling location. Groundwater and/or soil samples were collected from 19 boring locations. Samples were tested for PAHS and BTEX.

Free product was encountered at five sampling locations north of Quendall Pond and west of the North Sump. The product was encountered in a sand layer immediately above a silty clay layer.

1.5 Disclaimer

Any work or work product addressed in this document or cross-referenced herein and performed or to be performed by the City in the identified Quendall Terminals area has been or will be undertaken only for the purpose of determining the feasibility of the redevelopment project. This analysis is only applicable for the developments currently under consideration.

The City is submitting this document with the understanding that no independent liabilities shall be assumed by the City under MTCA or any comparable federal or state environmental laws should the City elect not to complete the Quendall Terminals property purchase. The current owners of the Quendall Terminals property have authorized this submittal without being committed to, or bound by, the content of this RI/FS.

2 Physical Site Setting

This section describes the site geology, hydrogeology and the site lacustrine environment. Previous investigations were summarized in the Remedial Investigation Report (Hart Crowser, 1997) and lacustrine information collected by ThermoRetec was summarized in the Sediment Quality Memorandum (RETEC, 1997m). The purpose of this section is to outline physical characteristics of the site that may impact contaminant migration and distribution or the selection of cleanup approaches.

2.1 Hydrogeologic Setting

2.1.1 Regional Geology

The Quendall Terminals Property is located within the Puget Sound Basin, which is situated between the Olympic Mountains to the west and the northern Cascade Range to the east. The regional topography and subsurface geology have been extensively shaped by Pleistocene glaciation, with at least five major advances of glacial ice across the Puget Sound Basin (Galster and Laprade, 1991). These glacial advances and retreats, along with interglacial periods of erosion and deposition have produced a very complex mixture of drift, till and outwash sediments combined with fluvial, lacustrine and mud flow deposits.

The Vashon Glaciation is the most recent of these episodes, and the Vashon Drift mantles much of the surface within the Puget Sound Basin and northward into Canada. The Vashon Drift is generally differentiated into four members: the Lawton Clay, Esperance Sand, Vashon Till and Vashon Recessional deposits. In some lower-lying areas, these members have been eroded or covered by Holocene lacustrine and fluvial deposits.

Physiographic divisions made by Galster and Laprade (1991) place the Quendall Terminals Property within the southeast-northwest trending Kennydale Channel, which bisects the Newcastle Hills promontory to the north from the Coalfield Drift Upland to the south and terminates on the eastern edge of the Lake Washington Trough. Glacial troughs such as the Kennydale Channel typically include high energy Vashon recessional deposits of coarse sand, gravel and cobbles with some deeper, glacially compacted till possibly present, all overlain by Post-Vashon fluvial and lacustrine deposits of gravel, sand, silt, clay and peat.

Bedrock has been locally mapped at or near the surface in a generally east-west trend, forming Alki Point in West Seattle, Beacon Hill in Seattle and the Newcastle Hills east of Lake Washington and then continuing east toward the northern Cascades. The core of the Newcastle Hills promontory is composed of middle to late Eocene Tukwila and Renton Formations of the Puget Group. The Tukwila Formation consists of volcaniclastic sandstone, siltstone and shale, with the conformably overlying Renton Formation composed of arkosic sandstone, siltstone, shale and coal (USGS, 1970). Extractable coal seams in the Renton and Black Diamond areas ranged from 11 to 17 feet in thickness where mining began in the early 1870s. Due to folding and faulting of the Renton Formation and undifferentiated Puget Group, the mines tended to be small and the mining conditions difficult. Subbituminous coal from the Renton Number 1, 2 and 3 seams was extracted from the Renton area, with bituminous coal mined from the McKay seam in the Black Diamond area.

2.1.2 Site Geology and Hydrology

The Quendall Terminals Property is located on the eastern shore of Lake Washington on the former delta of May Creek, which is an underfit stream remaining within the glacial Kennydale Channel. The subsurface geology of the site is a combination of fluvial, deltaic, lacustrine, nearshore and constructed fill deposits overlying Pleistocene glacial sediments and Eocene volcanic and sedimentary bedrock. The shallow geology at the project area has been heavily influenced by recent human activity, beginning with construction of the Lake Washington Ship Canal in 1916. This lowered the level of Lake Washington approximately 8 feet, and exposed a significant area of the May and Gypsy Creek deltas, which had formerly been submerged.

An interpretation of the project area subsurface geology has been made using soil boring and monitoring well geologic logs and test pit sidewall descriptions, which have been generated by environmental and geotechnical investigations in the area. The subsurface geology has been segregated into five major units:

- The Fill Unit,
- The Upper Sand Unit,
- The Silty Peat Unit,
- The Lower Sand Unit, and
- The Sandy Gravel Unit.

These five units comprise the subsurface interval, part of which has been impacted by past site activities or which could influence groundwater movement through an impacted area. These major units also include some localized subunits, which are further described below. Representative cross sections of the Quendall Terminals subsurface geology are presented on Figures 2-1 through 2-4.

Fill Unit

The fill unit ranges in thickness across the project area up to 14 feet with greater thickness along the shoreline. The fill zone includes dredged material consisting primarily of silty- to medium- grained sand, as well as imported material including clay, silt, sand, gravel, construction rubble, wood and other debris. The dredged fill appears very similar to May Creek deltaic deposits and it is difficult to differentiate without the presence of discarded debris or other obvious indicators. On most of the site, the fill zone corresponds to the unsaturated zone, although some sections of fill material are located below the shallow water table.

This fill unit has a wood waste subunit that is predominately located offshore in the southwestern corner of the Quendall Terminals property (Figure 2-2). It ranges in thickness from 0 to 5 feet (averaging 3 feet) and is composed of 90 to 100% wood waste and up to 10% silt and sand. The inner harbor of the Quendall Terminals was used as a log raft storage area and bark accumulated below these rafts; forming this unit.

Upper Sand Unit

The upper sand unit ranges in thickness from 0 to 25 feet and is located above the silty peat unit. This unit consists of fine to coarse, loose, wet sand with occasional silt and peat lenses up to 1 or 2 feet thick. It is brown to greenish-gray and locally silty to the north and east and gravelly towards the south and west. The upper sand unit is the main water-bearing unit of the upper aquifer and contains NAPL and dissolved contamination.

Within the upper sand unit there is an upper silty sand subunit that is vertically and horizontally non-continuous throughout the property. It is located above the silty peat and ranges in thickness from 0 to 10 feet. It is comprised of silt and sand, with occasional lenses and interbeds of clay, silt, and sand. It is locally gravelly, gray to tan and medium dense.

Silty Peat Unit

The silty peat unit is comprised of soft to stiff dark brown to gray silty peat, mica rich organic silt and silty fine-grained sand with interbedded gray and brown clay, silt, sand and occasional ash lenses. The organic matter in this unit consists of twigs and leaves. The silty peat acts as an aquitard (confining layer) between the upper and lower aquifers and appears to prevent DNAPL from sinking to the lower aquifer. The DNAPL tends to pool on the surface of the silty peat. This silty peat unit is most prominent in the northern segment of the Quendall Terminals log yard. The silty peat unit was encountered in soil borings with thicknesses up to 15 feet (average thickness of 4 feet), and was noted at depths up to 24 feet below ground surface (bgs) (average depth of 10 feet). The silty peat unit is generally sloping west toward Lake Washington except for the area around BH-17A and BH-17B in the southeast corner of the property where the silty peat slopes off to the southeast. Water levels in wells that intercept the upper fill and silty peat units are shallow and relatively stable, with depths to water between 7 and 13 feet. The average shallow groundwater contour map for the project area is shown on Figure 2-5 (RETEC, ****).

Lower Sand Unit

The lower sand unit is generally located directly beneath the silty peat unit, occasionally beneath the silty sand unit, and always above the sandy gravel unit. The lower sand unit is greenish to dark gray, loose, fine to coarse-grained sand with occasional gravel and interbedded gray and brown silty fine- grained sand and silt lenses.

The lower sand unit has a lower silty sand subunit located predominately in the northern portion of the Quendall property and is similar in composition to the upper silty sand subunit. This subunit consists of gray silty sand to fine sand and silt, soft to stiff, wet with local gravel and clayey silt and silty peat lenses and interbeds. The subunit also contains trace organics. This unit ranges in thickness from 0 to 25 feet.

Sandy Gravel Unit

The sandy gravel unit is the lowest unit observed on the Quendall property, with a known thickness of 50 feet or more. The sandy gravel unit consists of fine to coarse-grained gravel up to 1 inch in size and fine to coarse sand. This unit is gray, very dense, saturated and is the primary water bearing unit for the lower aquifer below the silty sand unit.

The hydrology of the Quendall Terminals property is characterized by a shallow unconfined water table aquifer and a lower moderately confined aquifer below the silty peat unit. The water table aquifer recharges in the upland to the east of the site, has a groundwater flow toward the west and discharges into Lake Washington. Groundwater modeling performed by RETEC for the Port Quendall development area suggests that shallow groundwater currently discharges to the lake within 60 feet of the shoreline. According to the site well gauging data, the lower confined aquifer has a potentiometric surface that is lower than the upper water table toward the east and higher than or equal to the upper water table toward the shoreline (RETEC, 1998).

2.1.3 Hydraulic Parameters

Shallow wells are generally screened across the upper sand, silty peat, and lower sand units, as a result, shallow hydraulic data represents a composite of these three units. Hydrogeologic investigations of these shallow layers have resulted in hydraulic conductivity estimates ranging from 0.3 to 30 feet per day (ft/day). The average conductivity estimate for the layer is 3 ft/day. The heterogeneity of the layer is reflected in the large range of the estimated values. The lower estimates are associated with silt and clay lenses, whereas the higher values are associated with sand lenses. Six wells are screened over both the shallow layer and a saturated portion of the fill unit; the conductivity estimates from these wells were analyzed as part of the shallow layer.

Two slug tests were completed in the sandy gravel unit and provide an estimated hydraulic conductivity of 5.7 ft/day and 57 ft/day.

Previous investigations have estimated the shallow layer porosity between 0.28 and 0.32 (unitless) (Woodward Clyde, 1990). Based on site data, the effective porosity of the sandy gravel unit is estimated between 0.20 and 0.25.

2.2 Site Lacustrine Environment

The property includes approximately 1,400 linear feet of Lake Washington shoreline. The use of Lake Washington has been an important component of past site activities, including barge off-loading, ship berthing and log storage. The current shoreline characteristics range from gently sloping vegetated shorelines to abrupt rip-rap shorelines.

Three wetlands exist onsite (wetlands A, B and C) and are shown on Figure 2-6. Hydrology in wetlands A and B is controlled by the lake level, and only minor surface discharge enters these areas. Wetland C is a remnant of the historical Quendall Terminals pond. This area appears to be isolated from groundwater and receives drainage from the adjacent log yards (Beak 1997).

The Quendall Terminals log dump is at the southern end of the property. The shoreline in this vicinity is abrupt, having been partially bulkheaded and armored with riprap. There is no significant beach in this area. In addition, there is no upland vegetation in this area because of industrial activities (scrap off-loading, log handling) conducted there.

2.2.1 Lake Bottom Characteristics

As shown by the bathymetric contours on Figure 2-7, the lake bottom is relatively flat between the inner and outer harbor lines. The average slope over this interval is 3 feet vertical and 100 feet lateral. Water depths at the outer harbor line range from 26 to 31 feet (as measured at normal high water line) in most of the area. The bathymetric survey is consistent with USGS maps for the area. These show similar water depths at the outer harbor line. The USGS maps also show that on a transect toward Mercer Island from the Quendall Terminals property, the maximum water depth reached is approximately 70 feet.

The nearshore bathymetry is less uniform than that in the outer harbor area, ranging from gradual slopes to relatively steep slopes and bulkhead areas. In addition, there is a sand spit located just north of the mid-Quendall shoreline.

Acoustic surveys of the Harbor Lease areas confirmed that logs, log bundles and other debris are present on the lake bottom. Log densities ranged from less than 1 log per acre near the outer harbor line, to greater than 5 logs per acre near the Quendall log dump. Three log bundles were identified on the lake bottom.

Just to the north of the Quendall Terminals property, utility lines were located on the lake bottom offshore from the PSPL substation and the Metro inceptor pumping station. These locations are consistent with easements for those utilities. The lines are located approximately 400 feet to the northeast of the Quendall T-Dock.

Besides the logs and utility lines, the survey identified other debris including concrete anchors and metal debris. The amount of this debris was limited compared to the log debris. Approximately 47 pilings and dolphins were mapped within the Harbor Lease areas during the site survey, excluding the pilings associated with the Quendall Barge Dock. The pilings and dolphins are located in all areas of the site in water depths ranging from less than 5 feet up to 30 feet.

2.2.2 Sediment Particle Size

A sediment profile imaging (SPI) survey provided generic information about the particle size distribution for the sediments. In general, the lake bottom sediments consisted of a fine silt/mud with a small particle size. However, there were several areas in which a more sandy bottom was evident in the SPI images, including:

- Quendall Sand Spit
- Quendall sediment near the outer harbor line

During the beach surveys, additional areas of sandy sediment were noted. These included two short stretches of beach along the Quendall terminals property. One of these was located north of the former mouth of May Creek, just north of the Quendall log dump. The second was located just south of the Quendall sand spit. In this latter location, the beach was generally covered with a thick layer of wood waste and bark, but sand was noted at water depths ranging from 1 to 4 feet below the low water line.

2.2.3 Sediment Infauna, Macrofauna and Flora

During the SPI survey, video transects, and sediment grab sampling, observations were made regarding sediment-dwelling organisms, macrofauna and flora. These observations were qualitative in nature, as they were collected inadvertently during sampling for other parameters. Sediment-dwelling infauna noted during sampling included the following:

- Chironomids
- Amphipods
- Oligochaetes
- Annelids

Macrofauna noted during video transects and grab sampling included the following:

- Freshwater clams and mussels
- Crayfish
- Smallmouth bass
- Sculpin
- Perch
- Sockeye salmon

Areas of milfoil were also noted in the side-scan sonar and video surveys, with dense milfoil areas characterized by water depths between 5 and 15 feet.

3 Nature and Extent of Contamination

Several investigations of potential contamination within the Quendall Terminals Property have been performed, generating a large volume of chemical data and visual observations of soil quality. Comprehensive summaries of project area historical information, regulatory records, and environmental data have been provided in the Remedial Investigation Report (Hart Crowser 1997). This existing data was incorporated with data collected by ThermoRetec during the previous due diligence process and subsequent investigations to develop an interpretation of current site conditions. This interpretation of site conditions is then compared with the cleanup levels discussed in Section 4 to determine the extent of cleanup actions required, thereby allowing conceptual design and cost estimating of cleanup alternatives.

3.1 Source Area Identification

As described in Section 1.4, development of the subject property commenced in the 1916 with construction of a tar refining facility. Figure 1-2 provides the approximate locations of the former Quendall Terminals operations areas discussed below.

3.1.1 North Site Area

- Disposal of steam condensate to a sump (North Sump) located northwest of the still, which was reportedly excavated and closed when the plant was shut down; a second sump (South Sump) was located in the central site area and has been buried.

- A pitch storage bay north of the still area where mounds of material can be seen in 1936 and 1946 aerial photographs.

- A low-lying marshy area and drainage ditch that existed in the northwest site area; there are reports of still bottom and tank bottom disposal in this area.

3.1.2 East Site Area

- Water supply wells along the east site boundary, which reportedly became contaminated over time.

- The still house, which had a dirt floor and spillage reportedly occurred.

- Rail loading facilities south of still near original Tanks 1 through 5.

- Loading rack on the east side of the railroad tracks across from the still area.

3.1.3 South Site Area

- Discharge of still condenser leakage to the sewer lines, especially to a sewer outfall in the southern site area.
- A dump area just south of the original tanks (Tanks 1 through 5) in the approximate area of an old drainage channel.

3.1.4 Offshore Area

- A substantial spill of creosote/coal tar in the 1940s at the end of the wharf and pipe trestle (T-pier) during off-loading operations (estimated at 30,000 gallons).
- Overfilled drip pans observed at the end of the short 1916 dock.

3.2 Data Sources and Validity

Nearly 50 environmental and/or geotechnical studies are known to exist for nearby properties, dating from 1963 to the present. Data from these studies provided project area subsurface geological information as well as soil, groundwater, and vapor analytical data. Figures showing data locations, depths, and results used to determine impacted soil volumes were provided in the Upland Constituents Memorandum (RETEC, 1997f). Groundwater data was also summarized in the Upland Constituents Memorandum (RETEC, 1997f) and sediment data and impacted areas were summarized in the Sediment Quality Memorandum (RETEC, 1997m).

A detailed summary of environmental samples collected from the former operation areas of the Quendall Terminals Property is included in the Remedial Investigation Report (RI; Hart Crowser, 1997). A summary of previous investigations, including additional site characterization work performed by ThermoRetec in 2001, was provided in Section 1.4. The amount of site data that has been collected is adequate to allow for analysis of feasible remedial alternatives. Figure 1-3 illustrates the location of all investigation smapling locations at the Quendall Terminals Property.

3.3 Soil Impacts

Elevated PAH concentrations have been detected in upland soil. Soil impacts range from low-level (µg/kg) concentrations of heavy-end coal-tar residuals to percent-level PAH contamination in other areas. Also, localized areas contain free product, and other areas are impacted by light-end coal-tar distillates such as benzene (RETEC 1996b). Contamination of site soils with PAH compounds and benzene is discussed below.

3.3.1 Polycyclic Aromatic Hydrocarbon Compounds in Soil

Soil samples for PAH analyses were collected over a range of depths from ground surface to a maximum sample depth of 44 feet below ground surface. The analyses were performed using EPA Method 8270 and various field screening methods including gas chromatography screen, fluorescence screen, and immunoassay analytical techniques. Appendix A includes all available soil analytical results for individual, total, and carcinogenic PAH (CPAH) compounds at each location and date; the method of detection; and the depth interval of the sample. The fluorescence screening data were not available for inclusion in this report.

Figures 3-1 and 3-2 show the concentrations of total PAH and CPAH compounds in onsite soil based on EPA Method 8270 analytical results. The figures show the concentration of total and CPAH compounds at the depth sampled for each location.

Estimated total PAH (TPAH) concentrations ranged from below the detection limit to 37,220 mg/kg (HC-7). The individual PAH compound found at the highest concentration was naphthalene, at a concentration of 11,000 mg/kg in a sample from HC-7. Figure 3-1 shows the TPAH concentration in soil detected at zero to 20 feet bgs by EPA Method 8270 between 1983 and 2001. Total CPAH concentrations (Figure 3-2) ranged from not detected to 10,008 mg/kg (TP-4). The highest individual cPAH concentration was for chrysene, at a concentration of 2,500 mg/kg in a sample from TP-4. The ratio of CPAH to TPAH at a given sampling location averaged 0.24 and ranged from 0 to 0.68 indicating that lower weight PAHs are more abundant at the site than the CPAHs. Areas of highest PAH and CPAH concentrations are generally encompassed by areas of DNAPL.

3.3.2 Benzene in Soil

Benzene was detected primarily in areas affected by DNAPL (Figure 3-3). Benzene analyses were generally performed using either EPA Method 8020 or 8260 with detected concentrations ranging from 170 to 4,800 µg/kg. The maximum concentration was found in the sample from RB-9 in 2001. Appendix A includes soil analytical results for benzene.

3.4 Groundwater Impacts

Past activities at the Quendall Terminals site have resulted in impacts to groundwater quality. PAH compounds and benzene have been detected in groundwater. The nature and extent of these chemicals in groundwater is discussed in more detail below. Saturated zone NAPL is also discussed in this section.

3.4.1 Polycyclic Aromatic Hydrocarbons in Groundwater

Appendix B includes all available PAH data for site groundwater. Results show that areas of elevated PAH concentrations in groundwater appear to be associated with the former May Creek channel, the still house area, Quendall Pond, and the north sump area.

The 2001 mudline investigation conducted by RETEC included groundwater sampling of 10 shoreline wells and 18 wellpoint locations in Lake Washington at multiple depths in the upper and lower water-bearing aquifers. Concentrations of total PAH in groundwater ranged from non-detect to 15,098 µg/L (WP-19A), with the primary constituent being naphthalene. The highest naphthalene concentrations were found in the shallow groundwater at locations associated with the Quendall Pond area (WP-19A, WP-19B, and BH-20A). Figures 3-4 and 3-5 shows the naphthalene concentrations detected in the shallow and deep groundwater. Carcinogenic PAHs were detected only in two monitoring wells and one wellpoint as indicated on Figure 3-6.

3.4.2 Benzene in Groundwater

Benzene data is given in Appendix B. Previous investigations indicated that areas of elevated benzene concentrations appear to be located in the areas associated with DNAPL contamination—the former May Creek channel, the Quendall Pond area, the still house area, and the north sump area. The 2001 mudline investigation confirmed these findings with concentrations of benzene in the affected areas ranging from not detected to 12 mg/L. Benzene impacts in the deep aquifer appear to be predominantly associated with Quendall Pond area with monitoring well BH-20B having the highest benzene concentration at 3.2 mg/L. Figures 3-7 and 3-8 show the benzene concentrations detected in the groundwater.

3.4.3 Dense Non-Aqueous Phase Liquid

During soil and groundwater sampling, free creosote and tar materials were reported in multiple areas of the Quendall Terminals property. Boring, well, and trench logs for the property include written observations describing liquid product and nonliquid residuals such as pitch, coke, coal-like materials, and stained soils. The available logs and field observations of soils showing evidence of product were compiled by RETEC.

From the historical logs and data, onsite areas affected by DNAPL were identified and are shown in Figure 3-9. The occurrence of DNAPL has been identified in five areas of the site:

- North sump area
- South sump area

- Quendall Pond
- Still house area
- Former May Creek channel.

Much of the hydrocarbon product noted in boring logs is present below the water table. However, the product appears to have remained within a sandy layer immediately above a silty peat layer present in the shallow soils. The free product was analyzed, and the results showed a distribution of PAH compounds and the presence of dibenzofuran and carbazole, consistent with a creosote or coal-tar source.

Based on the location and depth of the DNAPL observed in Lake Washington sediment, it appears that the nearshore area is affected by DNAPL originating from upland seeps. Sediment DNAPL locations are adjacent to confirmed deposits of upland DNAPL and areas of elevated naphthalene and benzene concentrations in groundwater.

North Sump Area

During operation of the Reilly Tar and Chemical refinery, wastewater was discharged to the north sump, which collected settleable solids. The north sump was excavated to remove free product after the refinery closed; however, DNAPL was subsequently detected in several borings. DNAPL was detected in boring VS-2 offshore from the north sump area, in a direction consistent with the reported surface water discharge from the sump to Lake Washington. However, subsequent borings in the vicinity did not indicate the presence of DNAPL. Furthermore, data collected from the geoprobe delineation investigation in 2001 indicates that the plume is moving in a more westerly direction as indicated on Figure 3-9. These findings are confirmed by the 3D illustration of the silty peat surface that shows troughs in the silty peat layer that contain product.

South Sump Area

The south sump received effluent from cooling lines and contaminated with creosote and tars. Free product has been encountered in one boring (BH-8) located in the south sump area, but not in other borings in the vicinity. The product is contained as a pool on a silty peat layer within the sand shown in Figure 2-3.

Quendall Pond

The Quendall Pond plume is shown in Figure 3-9. Along the shoreline downgradient of Quendall Pond, DNAPL was observed in two vibracore samples, VS-30 and VS-4. The DNAPL in core VS-4 was overlain by materials containing no evidence of contamination, indicating that the DNAPL had moved to that location by means of lateral transport. The DNAPL detected in VS-30 was at an intermediate location between the uplands DNAPL and that found in VS-4. No DNAPL was noted in the four cores taken downgradient of VS-4 (VS-27, VS-20, VS-17, and core F), thereby defining the westernmost boundary of the plume in the vicinity of VS-4.

Still House

NAPL was reported in several borings (HC-5, B-4, HC-4, and BH-25A) in the still house area which includes several historic tank sites. As with the other plumes, the product is contained within the shallow unit.

Former May Creek Channel

DNAPL present in the former May Creek channel does not appear to extend to the shoreline, which is located less than 150 feet away. DNAPL associated with the former May Creek channel appears to be pooling on the silty peat in a topographic low in the vicinity of BH-21A.

3.5 Sediment Quality

Existing sediment data was gathered by Twelker (1971), U.S. EPA (1983), Ecology (1992), RETEC (1997b), and Exponent (2000). Sampling by RETEC (1997b) consisted of over 80 grab samples, Vibracore deep sampling, a sediment profile camera survey, a diver survey, a towed-camera video transect survey, beach surveys, bathymetric surveys, and side-scan sonar surveys. The results of these previous investigations with regard to the characteristics of wood waste and debris in the sediments, and PAH and benzene contamination, are discussed below.

The following discussion of PAH and benzene contamination in sediment is divided into two geographical areas: nearshore sediment and sediment in the T-dock area of the Quendall Terminals site. The sediment wood waste discussion reviews the protocol used to quantify wood waste and determine the environmental impact of the wood waste. All available sediment contaminant data are presented in Appendix C.

3.5.1 Polycyclic Aromatic Hydrocarbons in Sediment

In the nearshore area, PAH contamination in sediment was detected at concentrations up to 28,644 mg/kg (EPA-1) (Figure 3-10). High PAH concentrations were generally found in the DNAPL-affected areas. PAH concentrations were measured at multiple depths to determine the extent of shallow-zone contamination. Samples from areas showing no evidence of DNAPL (VS-27, VS-20, VS-18, and VS-21) all indicated a shallow contaminated zone that is less than 2 feet deep (RETEC 1997b).

In the T-dock area, contamination is assumed to have originated from coal-tar spills during historical operations (RETEC 1997b). The PAH contamination at the T-dock is generally present in a discrete layer less than 1 foot thick with a maximum depth of 3.5 feet. Vibracore samples revealed coal-tar contamination in the upper few inches of sediment. Cleaner material was often found overlaying the contaminated layer (samples S-51, S-60, S-46, S-45). The deepest reported PAH contamination was 297 mg/kg at 2.5 feet (EPA-1). No DNAPL seeps or pockets of contamination were noted in core tubes advanced to a depth of 17 feet below the mudline (RETEC 1997b). Data from RETEC's Phase I sampling event was combined with the earlier EPA and Ecology investigations to estimate the area of sediment where PAH concentrations exceed 100 mg/kg (Figure 3-10). The total area of sediments with PAH concentrations exceeding 100 mg/kg in the T-dock area was calculated to be approximately 12,400 square yards (RETEC 1997b).

3.5.2 Benzene in Sediment

In the nearshore area, elevated benzene concentrations were detected in vibracore samples during RETEC's Phase II sampling. Benzene was detected in sample VS-30 (nearshore north sump DNAPL area) at a concentration of 260 mg/kg; in sample VS-29 at a concentration of 24 mg/kg; and in sample VS-21 at a concentration of 0.78 mg/kg (RETEC 1998), suggesting that these borings are located near a DNAPL source.

In the T-dock area, the most heavily contaminated sediment samples (S-45B, S-46B, S-51B) and a number of other samples were tested for benzene and other volatile organic compounds during RETEC's Phase I sediment investigation. Benzene was not detected in any of these samples (detection limits ranged from 0.0012 to 69 mg/kg). The lack of benzene detections in the T-dock sediment is attributed to attenuation of volatile organic compounds due to weathering and leaching (RETEC 1997b).

3.5.3 Wood Waste in Sediment

During the Quendall Terminals feasibility study process, RETEC, Ecology, and the resource agencies developed a measurement protocol for quantifying the extent of wood waste in sediment within the project area. Wood waste is regulated by Ecology as an "other deleterious substance" as defined by the Sediment Management Standards (SMS). The extent of wood waste was determined during RETEC's Phase I and Phase II investigations (RETEC 1997b).

As defined in Ecology's protocol, sediment exceeding 50 percent wood waste by volume is assumed to be deleterious and require remedial action. No additional testing was considered necessary for characterization of this sediment (RETEC 1997b). From the sediment profile imaging survey, the percent of wood by volume was measured for the 0 to 10 centimeter depth interval by measuring the two-dimensional area of wood material visible in the sediment profile images. The lateral coverage of wood waste in sediment was then measured using the video transect data. An area exceeds the remedial action threshold if both the sediment profile imaging survey and video transect data show greater than 50 percent wood waste. The principal area of wood waste exceeding 50 percent was identified as the area offshore of the Quendall Terminals log dump (Figure 3-11). The volume of the wood waste/sediment is approximately 48,000 cubic yards (RETEC 1997b).

3.5.4Benthic Habitat

The sediment that showed less than 50 percent wood waste was screened to estimate disturbance levels (RETEC 1997b). One measure of benthic disturbance is the thickness or depth of the oxygenated zone of the sediment. The depth at which oxygen becomes limiting is the redox potential discontinuity (RPD), described in more detail below.

In addition to providing information about the volumetric percentage of wood waste in the sediment, the sediment profile images provided a measurement of the RPD thickness. The RPD is identified as the depth to which particles with oxidized coatings persist in the sediment column. Typically the oxygenated sediments exhibit an olive or tan color (iron oxides indicating oxygenated conditions), whereas the underlying reduced (oxygen-poor) sediments are gray to black as a result of iron sulfide buildup. The boundary between the oxic tan sediment and the black to gray reduced sediment denotes the apparent RPD. The apparent RPD is an important measurement that integrates pore water dissolved oxygen conditions, sedimentary organic enrichment, and biogenic mixing rates over time (RETEC 1997b). In the case of Quendall Terminals sediment, three main factors may affect the RPD: 1) physical disturbance, such as logs rolling on the lake floor, 2) oxygen depletion due to inputs of large amounts of wood waste, leading to bacterial breakdown of the wood, and 3) oxygen depletion due to bacterial degradation of contaminants in the lake sediments. A lack of oxygen diminishes the depth of the RPD and may result in diminishing populations of benthic infauna and macrofauna supported in the sediments.

The RPD can be useful to assess the physical and biological quality of a habitat for epifauna and infauna. The depth of the apparent RPD in profile images has been shown to be related to the quality of the benthic habitat in marine and estuarine sediment (Rhoads and Germano 1986; Revelas et al. 1987; Day et al. 1988; Diaz and Schaffner 1988a; Valente et al. 1992). Accounting for differences in sediment type and physical disturbance factors, thin RPDs may be indicative of chronic benthic environmental stress or recent disturbance.

Relative trends in apparent RPD depths are indicative of overall benthic disturbance regimes. Thinner RPDs generally point to areas subject to either physical stress (e.g., scouring by prop wash) or chemical stress (e.g., high sediment oxygen demand or chemical contamination). The shallowest RPD depths at the site (less than 0.2 cm) occurred in a contiguous nearshore area that stretched between and connected the areas with greater than 50 percent wood waste. This reduced RPD thickness could be due to the physical disturbances caused by grounding and rolling of log debris, prop wash from log handling boats, and organic enrichment resulting from the widespread inputs of wood waste. A strong population of sediment-reworking benthic infauna was observed in undisturbed areas. However, in the inner areas of the site, the disturbance appears to have prevented similar benthic infaunal development (RETEC 1997b).

Surrounding the highly disturbed area, a broad swath of the lake bottom exhibited intermediate RPD values (0.2 to 0.8 cm). This region extended from the outer harbor line off of the Quendall Terminals property, south past Barbee Mill to the May Creek delta (Figure 3-11). Stresses to the benthic environment in this area are likely varied. Both scattered wood debris and localized PAH contamination may influence benthic assemblages. In addition, natural disturbance factors such as inputs of labile organic matter from decomposing submerged aquatic vegetation (e.g., milfoil), or physical scouring at the delta may be contributing benthic stress factors along the shoreline at the northern and southern ends of the area.

The remainder of the survey area exhibited RPD depths greater than 0.8 cm. This included the areas west of Quendall Terminals and the entire area north and northeast of the former T-dock. Based on the uniform distribution of RPD depths across these outlying regions, these relatively deep RPD areas appear to represent a relatively undisturbed benthic condition in terms of overall animal-sediment interactions for nearshore areas in this portion of Lake Washington. Additional data regarding the distribution of biological features, infaunal sediment texture, and other sediment profile imaging parameters were summarized by Striplin (1997).

3.5.5 Gray Zone

Exponent conducted an assessment of the sediment at the Quendall Terminals property in the summer of 2000 (Exponent, 2000). The objective of this assessment was to determine whether deleterious effects on benthic organisms are associated with the "gray zone" sediment that had been identified in previous site investigations based on the criteria of a wood waste content of less than 50 percent and an observed redox potential discontinuity of less than 0.8 cm. The potential for deleterious effects on benthic organisms was assessed using laboratory toxicity tests conducted with field-collected sediment samples. Ancillary data were also collected on physical and chemical characteristics of the sediment samples.

The testing methods and interpretative guidelines were developed in consultation with Ecology and were discussed with representatives of the U.S. Army Corps of Engineers, the Washington Department of Natural resources, the U.s. Environmental Protection Agency (EPA), and the Muckleshoot Tribe. Conceptually, the guidelines parallel the marine sediment quality standard (SQS) and cleanup screening level (CSL) guidelines are included. The Washington SMS define the SQS as representing "no adverse effects" level and, generally speaking, sediment needs not be considered for remediation unless toxicity results exceed the CSL guidelines. The results for each toxicity test conducted on the gray zone sediment were compared with site-specific SQS and CSL guidelines.

Laboratory toxicity tests conducted on the nine sediment samples and three reference sediment samples included a 10-day amphipod (Hyalella azteca) survival and growth test, a 10-day and a 21-day chironomid (Chironomus tentans) survival and growth test, and a Microtox™ 100-percent sediment porewater test. In addition to the test and reference sediment samples, each toxicity test required the use of a negative control sediment sample.

For both the H. azteca and the Microtox™ test, there were no exceedances of either the SQS or CSL guidelines. For the 10-day C. tentans tests, most of the effects were detected were relatively minor. The mean mortality results for the 21-day C. tentans test exceeded the CSL guidelines in several areas. There was no SQS or CSL exceedances for the biomass endpoint in the 21-day C. tentans test for any of the gray zone samples.

Each of the toxicity tests was given a weighting factor that represents a consensus of best professional judgment on how reliable the test is, its ecological significance, and its sensitivity. The results suggested that a large portion of the gray zone does not need be considered for remediation. The remaining gray zone (Figure 3-12) represents a CSL exceedance and requires remediation.

3.6 Site Conceptual Model

Figure 3-13 shows a conceptual model of contaminant sources and transport pathways through the central area of the Quendall Terminals site. NAPL and groundwater impacts can be correlated to source areas. NAPL distribution and migration is governed by site stratigraphy, and Figure 3-13 shows that DNAPL pools have accumulated in depressions in the top of the silty peat layer. Dips in the silty peat layer have caused DNAPL to migrate underneath Lake Washington.

Figure 3-14 shows the upper surface of the silty peat unit and includes the data points, upper and lower shorelines, and the Quendall property lines. This layer shows a high degree of heterogeneity both vertically and horizontally and is saturated over most of its depth.

Dissolved-phase groundwater impacts are closely correlated to the presence of NAPL. The NAPL beneath the lake has resulted in mudline groundwater concentrations that exceed surface water standards. The PAHs that have been detected in groundwater are predominantly the lighter-end PAHs, which are more readily treatable than the heavy-end constituents. Groundwater flow direction is toward Lake Washington.

4 Remedial Objectives and Cleanup Levels

This section develops appropriate remedial action objectives and cleanup levels for groundwater, soil, and sediment. A review of "legally applicable requirements" and "relevant and appropriate requirements" is performed to support selection of cleanup levels.

4.1 Media and Constituents of Concern

Groundwater, soil, and sediment have been determined to be the media of concern at the Quendall Property. These media have been predominantly impacted through contact with coal tar and coal tar distillates, although a portion of the sediment impact is based on benthic disturbance. The aforementioned media and the associated constituents of concern are presented in the following table.

Table 4-1 Media and Associated Constituents of Concern

Medium	Constituents of Concern
Groundwater	PAH Benzene
Soil	PAH Benzene
Sediment	Benthic disturbance in gray zone Greater than 50% Wood Waste PAH

4.2 Objectives

This section provides a brief summary of the overall objectives of remediation activities. These objectives have been selected based on compliance with MTCA and SMS regulatory criteria and the conceptual land-use proposed. Proposed objectives of remediation activities include:

- Protection of aquatic life in surface water and sediment from exposure to constituents of concern above protective levels,
- Protection of groundwater to a level that is protective of surface water and sediment,
- Protection of humans who consume aquatic organisms from exposure to tissue containing constituents of concern above protective levels,

- Protection of humans from direct contact with soil containing constituents of concern above protective levels, and
- Removal or containment of impacted sediment to a level that will create no adverse effects on biological resources and human health.

4.3 Potentially Applicable Requirements

MTCA requires that all cleanup actions comply with applicable state and federal laws (WAC 173-340-360(2)). MTCA defines applicable state and federal laws to include "legally applicable requirements" and "relevant and appropriate requirements."

4.3.1 Laws Applicable to Cleanup Levels

Those potentially applicable requirements that apply to cleanup and action levels are summarized in this section.

Table 4-2 Potentially Applicable Requirements—Cleanup Levels

Medium	Standard/Criterion	Citation	Comments
Groundwater Surface Water	Requirements for establishing numeric or risk-based goals and selecting cleanup actions.	Model Toxics Control Act (WAC 173-340, Sections 720 and 730)	Anticipated to be relevant and appropriate to site remediation. Surface water cleanup levels are reported in Table 4-5.
Sediment	Criteria used to identify sediments that have no adverse effects on biological resources and correspond to no significant health risk to humans.	Sediment Management Standards (WAC 173-204)	SMS cleanup levels have not been promulgated for fresh-water sediments. Site-specific cleanup levels are developed on a case-by-case basis as are cleanup levels for other deleterious substances (WAC 173-204-100(3))
Surface Water	Ambient water quality criteria for the protection of aquatic organisms and human health.	Federal Water Pollution Control Act/ Clean Water Act (CWA) (33 USC 1251–1376; 40 CFR 100–149) 40 CFR 131	MTCA requires the attainment of water quality criteria where relevant to the circumstances of the release. Ambient water criteria and Water Quality Standards for

			the human consumption of organisms at 1 × 10^{-6} risk is anticipated to be relevant for groundwater (Table 4-5).
Drinking Water	SDWA National Primary Drinking Water Standards: Maximum Contaminant Levels (MCLs), Maximum Contaminant Level Goals (MCLGs), Proposed MCLs and MCLGs.	Safe Drinking Water Act (SDWA) 40 CFR 141	Not anticipated as applicable to surface water cleanup levels due to restriction on Lake Washington water rights (WAC 173-508).
Surface Water	State water quality standards; conventional water quality parameters and toxic criteria.	Washington Water Pollution Control Act - State Water Quality Standards for Surface Water (RCW 90.48) WAC 173-201A-130	Narrative and quantitative limitations for surface water protection. Lake Washington has been classified as "Lake Class" water, although restrictions on Lake Washington water rights (WAC 173-508) indicate that the characteristic use of water for water supply is not applicable and the "Lake Class" designation only applies to aquatic resource protection.
Listed Hazardous Waste	Federal standards for identifying and managing hazardous wastes.	Resource Conservation and Recovery Act (RCRA) (40 CFR 261.24.10–11 Subpart B).	Not anticipated as applicable since hazardous waste will not be generated during cleanup.

4.3.2 Laws Applicable to Treatment and Disposal

This section provides a summary of laws that impact the management of soil, water, and sediment during the treatment and disposal process. These requirements may impact the implementability and cost of remedial alternatives.

Table 4-3 Potentially Applicable Requirements—Treatment and Disposal

Activity	Requirement	Citation	Comments
Discharge to Surface Water	Point-source standards for discharges into surface water bodies. Applicable to point-source discharge or site runoff directed to surface water body. Federal criteria for water quality to protect human health and aquatic life. Enforced under state water quality laws and MTCA. State Water Quality Standards for Surface Water.	National Pollutant Discharge Elimination System (NPDES) (40 CFR 122, 125) State Discharge Permit Program; NPDES Program (WAC 173-216, -220) Federal Water Quality Criteria (40 CFR 131) WAC 173-201-045 - 047	Anticipated to be relevant if discharged to on-site water body. Discharges must comply with substantive requirements of the NPDES permit. Applicable for off-site discharges, a permit would be required. Anticipated to be relevant for remedial measures involving this activity. Implementation of federal requirement to develop state water quality control plan. Narrative and quantitative limitations for surface and groundwater protection based on beneficial uses. Anticipated as relevant.
Point Source or Other Defined Emission Source	State implementation of ambient air quality standards. PSCAA ambient and emission standards.	Washington State Clean Air Act (70.94 RCW) General Requirements for Air Pollution Sources (WAC 173-400) PSCAA Regulations I and III	Potentially applicable to remedial actions.
Designation of Waste for Disposal	State criteria for dangerous waste, which are broader than federal criteria and include toxicity and persistence.	Washington Dangerous Waste Regulations (WAC 173-303) Designation procedures (Section -070)	The appropriate waste designation should be made for IDW or other waste generated during remedial actions, according to WAC 173-303-070(3)(i) through (iv). These procedures specify four types of dangerous waste determinations to be made: discarded chemical product

			(WAC 173-303-081), listed dangerous waste source (WAC 173-303-082), characteristic dangerous waste (WAC 173-303-090), and dangerous waste criteria (WAC 173-303-100). Further, waste subject to federal land disposal restrictions are considered dangerous (WAC 173-303-140).
Treatment, Storage, or Disposal of Hazardous Wastes	Effective November 8, 1988, disposal of contaminated soil or debris is subject to land disposal prohibitions or treatment standards.	40 CFR 268 Federal Land Disposal Restrictions; WAC 173-303-140, -141 Land Disposal Restrictions	Not anticipated as applicable since hazardous waste will not be generated during cleanup.
Storage or Disposal of Solid Wastes	Requirements for solid waste management.	Solid Waste Disposal Act 42 USC Sec. 3251-3259, 6901-6991) as administered under 40 CFR 257, 258; Minimum Functional Standards for Solid Waste Handling (WAC 173-304)	Applicable to non-hazardous waste generated during remedial activities.
Granular Activated Carbon Treatment	Meet design and operating standards for treatment and storage units for RCRA hazardous waste.	40 CFR 264 Subpart I Containers; 40 CFR 264 Subpart J Tanks; 40 CFR 264 Subpart X Misc. Units	Anticipated to be relevant if technology is implemented.
General Remediation	Requirement for use of all known available and reasonable technologies for treating wastewater from industrial sources prior to discharge to waters of the state.	State Water Pollution Control Act (RCW 90.48), Water Resources Act (RCW 90.54), Water Quality Standards for Surface Water (WAC 173-201A)	Anticipated to be applicable to remedial technologies involving discharges to surface water or groundwater.
Discharge to POTWs (Publicly Owned Treatment Works)	Contaminated water must be pretreated to certain limits prior to discharge.	National Pretreatment Standards (40 CFR 403); Metro District Wastewater Discharge Ordinance	Discharges to POTWs are considered off-site activities; pretreatment and permitting requirements would be applicable.
Listed Hazardous Waste	Federal standards for identifying and managing hazardous wastes.	Resource Conservation and Recovery Act (RCRA) (40 CFR 261.24.10–11 Subpart B)	Not anticipated as applicable since hazardous waste will not be generated during cleanup.

4.3.3 Other Remediation Requirements

Other potentially applicable requirements that apply to remediation activities are listed in this section. These requirements do not apply to cleanup levels or treatment and disposal activities, but place restrictions on how the remediation may be performed. These requirements will also be considered in the evaluation of alternatives for implementability and cost in this FS.

Table 4-4 Potentially Applicable Requirements—Other Remediation Activities

Location/Activity	Requirement/Prerequisite	Citation	Comments
Within 200 Feet of Shoreline	Construction near shorelines of statewide significance, including marine waters and wetlands.	Shoreline Management Act (RCW 90.58), Coastal Zone Management Act (16 USC 1451 et seq.)	Anticipated to be applicable.
Within 100-year Floodplain	RCRA hazardous waste facility designed, operated, maintained to avoid washout.	40 CFR 257 40 CFR 264.18(b) 40 CFR 761.75	Not relevant. Site not located in floodplain.
Within Floodplain	Actions that will occur in a floodplain (i.e., lowlands) and relatively flat areas adjoining inland and coastal waters must be performed so as to avoid impacts.	Executive Order 11988, Protection of Flood Plains (40 CFR 6, Appendix A)	Not relevant. Site not located in floodplain.
Disturbance of Greater than 5 Acres	NPDES Stormwater Permit for construction activity.	WAC 173-226 RCW 90.48	Anticipated to be applicable.
Within/Adjacent to Wetlands	Actions must be performed so as to minimize the destruction, loss, or degradation of wetlands as defined by Executive Order 11990 Section 7. Requirement for no net loss of remaining wetlands.	Executive Order 11990, Protection of Wetlands (40 CFR 6, Appendix A) EPA Wetland Actions Plan. (January 1989, OWWP)	Potentially applicable requirement; wetlands removed by cleanup activities will be replaced at 1.5 to 1 ratio and shoreline revegetation will be performed.
Critical Habitat upon Which Endangered or Threatened Species Depend	Actions must be performed so as to conserve endangered or threatened species, including consultation with the Department of the Interior.	Endangered Species Act of 1973 (16 USC 1531 et seq.) (50 CFR Part 200) (50 CFR Part 402)	Chinook salmon, bald eagle, and bull trout listed as threatened species.
Within State Siting Criteria for Waste Management Facilities	Siting criteria to be used as initial screen for consideration of solid or dangerous waste facility sites.	WAC 173-304 WAC 173-303-282(2)(b)(iii)	No new solid or dangerous waste management facilities are planned.

Construction in State Waters	Requirements for construction and development projects for the protection of fish and shellfish in state waters.	Construction in State Waters, Hydraulic Code Rules (RCW 75.20; WAC 220-1101), Rivers and Harbors Appropriation Act (33 USC 401, 40 CFR 230, 33 CFR 320, 322, 323, 325)	U.S. Army Corps of Engineers Nationwide 38 Permit anticipated to be relevant to dredging and filling below the mean high-water line.
Pump and Treat	Specifications for the extraction of groundwater or surface water that are waters of the state. Reporting requirements for new water treatment facility.	State Water Code and Water Rights (RCW 90.03, 90.14) Submission of plans and reports for construction of wastewater facilities (WAC 173-240)	Anticipated to be relevant for contingent remedial activities. Potential relevant if contigent groundwater remedies are triggered
Extraction/ Reinjection	Regulations and standards for the underground injection of hazardous waste and treated groundwater. State standards for discharges to surface water or reinjection.	Underground Injection Control Regulations (40 CFR 144-147; WAC 173-216, -218, -220; RCW 90.03, 90.14) WAC 173-154 Protection of Upper Aquifer Zone State Water Code and Water Rights	Potentially relevant if contingent groundwater remedies are triggered.
Groundwater Protection and Monitoring	RCRA maximum concentration limits applicable to releases from permitted RCRA-regulated unit (40 CFR 264.90)	Federal: 40 CFR 264.94 State: WAC 173-304-645(3)	Not anticipated to be relevant.
Air Emissions	National Primary and Secondary Ambient Air Quality Standards (NAAQS) for carbon monoxides, lead, nitrogen dioxide, particulate matter (PM_{10}), ozone, and sulfur oxides emissions from a "major" source.	Clean Air Act, Section 109; 40 CFR 50	Emissions from site not expected to qualify as major source unless: a) emissions are greater than 100 tons/year; or b) emissions of a specified air contaminant occur.
	Regional ambient air quality standards applicable to regulated air contaminant.	Puget Sound Clean Air Agency (PSCAA) Regulation III	Emissions from site not expected to qualify as major source unless: a) emissions are greater than 100 tons/year; or b) emissions of a specified air contaminant occur.

Air Emissions (Continued)	National Emissions Standards for Hazardous Air Pollutants (NESHAPs) for Industrial Emissions.	Clean Air Act National Emissions Standards for Hazardous Air Pollutants (NESHAPs), 40 CFR 61; WAC 173-400-075 State Emission Standards for Hazardous Air Pollutants	Not anticipated to be relevant.
	New Source Pretreatment Standards applicable to new source of hazardous air pollutants.	40 CFR 60	Potentially applicable to releases from remedial actions.
	Controls for New Sources of Toxic Air Pollutants for emission of any Class A or Class B toxic air pollutant (identified in WAC 173-460-150 through -160) into ambient air.	WAC 173-460	Potentially applicable to releases from remedial actions.
	Regional Emission Standards for Toxic Air Pollutants. Source of toxic air contaminant requires a notice of construction.	PSCAA Regulation III	Potentially applicable depending on remedial technology used.
	Regional Emission Standards for fugitive dust. BACT to control dust.	PSCAA Regulation I	Potentially applicable to releases from remedial actions.
Monitoring/ Extraction/ Recharge Wells	Standards for construction, testing, and abandonment of water and resource protection wells.	WAC 173-160-010 through -303, -050 through -060	Anticipated to be applicable requirement for remediation activities.
Noise Control	Maximum noise levels	Noise Control Act of 1974 (RCW 70.107; WAC 173-60)	Potentially relevant depending on remedial activities selected.
Habitat for Fish, Plants, or Birds Subject to State Fish and Game Department	Prohibits water pollution with any substance deleterious to fish, plant life, or bird life.	U.S. Fish and Wildlife Coordination Act (16 USC 661 et seq.)	Relevant requirement. Adjacent water body is used as a salmonid migratory route.
General Remediation	Site worker health and safety. Erosion and sedimentation controls.	WISHA (WAC 296-62) OSHA (29 CFR 1910.120) Puget Sound Water Quality Management Plan (RCW 90.70.070)	Relevant requirement for environmental remediation operations. Relevant requirement.

4.4 Potentially Applicable Cleanup Levels

This section presents cleanup levels which may be applicable for remediation efforts conducted at the Quendall Property. Specific selection of cleanup criteria and action levels will be discussed in more detail in Section 6 as they pertain to the selected remedial action.

4.4.1 Groundwater Cleanup Levels

Table 4-5 provides a list of potentially applicable cleanup levels for groundwater. These criteria include drinking water, surface water, and groundwater standards.

Maximum Contaminant Levels (MCLs) are defined by the EPA in Drinking Water Regulations and Health Advisories (EPA, 1996) as the "maximum permissible level of a contaminant in water which is delivered to any user of a public water system." MTCA defines standards for groundwater and surface water. MTCA Method A values are defined in WAC 173-340-700(3)(a) and their use is outlined in WAC 173-340-704. According to these guidelines, "Method A tables...are intended to provide conservative cleanup levels for sites undergoing routine cleanup actions or those sites with relatively few hazardous substances."

MTCA also defines risk-based Method B criteria (WAC 173-340-700(3)(b)) which "are established using applicable state and federal laws or the risk equations specified in WAC 173-340-720 through 173-340-750." According to WAC 173-340-705, "Method B is applicable to all sites." MTCA Method B Groundwater and Surface Water values are taken directly from the MTCA Cleanup Levels and Risk Calculations (CLARC II) Update (February 1996).

WAC 173-340-700(6) states that "Where cleanup levels are below the practical quantitation limit, compliance with cleanup standards will be based on the practical quantitation limit." Estimated quantitation limits (EQLs) for the PAH compounds and benzene are also included in Table 4-5. The EQLs listed are for EPA Method 8270, as provided in SW-846. Practical Quantitation Limits (PQLs) are instrument-specific, so SW-846 simply provides estimates (EQLs) of the PQLs and there is no standard reference for PQLs. Local laboratories were surveyed to obtain estimates of achievable PQLs using EPA Method 8270/SIM (selective ion monitoring). Various analytical labs were surveyed and provided PQLs ranging from 0.1 to 0.3 ug/L; these values are included in Table 4-5. A limited number of laboratories are able to achieve a PQL of 0.01 ug/L using EPA Method 8270/SIM-PRO.

Cleanup levels for groundwater were selected as the minimum of the applicable cleanup standards for protection of surface water and human consumption of organisms. In the event that this value was below the PQL, the PQL was selected as the cleanup level as specified in WAC 173-340-

700(6). No cleanup levels are available for acenaphthylene, phenanthrene, or benzo(g,h,i)perylene. To demonstrate that the proposed remedy will result in groundwater concentrations that are protective of sediment, modeling was performed.

4.4.2 Soil Cleanup Levels

Potentially applicable soil cleanup levels are presented in Table 4-6. The cleanup levels provided in this table include:

- MTCA Method B Direct Contact, and
- MTCA Method B 100× Groundwater.

MTCA Method B values are derived for protection of human health via direct contact with impacted soil and for protection of groundwater using a standard multiplier of 100 to account for contaminant leaching from soil to groundwater. These values are calculated using risk equations presented in WAC 173-340-720 through 173-340-750.

Each of the direct contact criteria is based upon a 10-6 risk per compound. MTCA allows a total risk of 10-5. Given that there are seven carcinogenic PAHs, using individual cleanup levels based on 10-6 yields a total risk of 7 × 10-6, which is lower than the acceptable total risk of 10-5 under MTCA.

Also, in proposed revisions to MTCA, Ecology has included an alternate method for calculating soil cleanup levels protective of groundwater based on chemical-specific partitioning. This alternate method is included in WAC 173-340-747 of the Revised Draft MTCA Rule Amendments (Ecology, 1998a). Once again, these calculations have not been performed since they will have little effect on these cleanup criteria and minor changes in the cleanup criteria will not impact the proposed soil remedy.

5 Remedial Technologies

This section identifies and screens selected technologies that are potentially applicable for remediation of soil, groundwater, and sediment at the Quendall Terminals site. The media-specific technologies were selected on the basis of the nature, type, and extent of contamination present at the site. In addition to the media-specific remediation technologies, site-wide monitoring and institutional control measures are identified and discussed.

A screening-level evaluation is provided to assess each media-specific technology in terms of the technology's probable effectiveness at achieving site remedial action objectives (RAOs), and in terms of the criteria specified by MTCA (WAC 173-340-360). This evaluation ensures that the most appropriate and representative technologies are carried forward for further evaluation in the cleanup action plan. Specific criteria used in the screening evaluation include:

- Effectiveness—The ability of the technology to meet RAOs, provide a permanent solution, address site-specific conditions, and minimize potential impacts on human health and the environment during implementation.

- Implementability—The technical and administrative feasibility of implementing the technology (e.g., administrative considerations include the ability to obtain permits and the availability of workers, equipment, disposal services, and supplies).

- Cost—The estimated capital and operation and maintenance costs of the technology.

Results of the screening of remediation technologies for soil, groundwater, and sediment are summarized in Tables 5-1 through 5-3. Specific applications of a given technology at the Quendall Terminals site are identified, as appropriate. Based on the screening evaluation, the most promising technologies were retained for potential incorporation into the remedial alternatives in Section 6.

5.1 Technologies for Remediation of Soil

This section discusses technologies potentially applicable for remediation of contaminated soil at the Quendall Terminals site. As discussed in Section 1.1, PAH compounds, benzene, and DNAPL contamination have been identified in soil at the site. The remediation technologies presented in this section include excavation, thermal desorption, incineration, bioremediation, offsite landfill disposal, soil washing, stabilization/solidification, capping, soil flushing, in situ vitrification, soil vapor extraction, and bioventing. Brief descriptions of each of these alternative technologies are presented along with a discussion of implementation implications for the Quendall Terminals site.

Excavation

Description of Technology—Excavation involves the use of conventional construction equipment (e.g., backhoe, front-end loader) to remove contaminated soil and clean overburden. Excavation may include shoring, localized control of groundwater and surface water, segregation and stockpiling of excavated clean overburden and contaminated soil, and backfilling and regrading. Much of the contaminated soil would require dewatering prior to treatment or disposal, and the water produced from dewatering would likely require treatment prior to disposal. Excavation of contaminated soil for ex situ treatment or disposal increases the potential for short-term exposure of workers to site contaminants.

Typical unit costs for excavation and excavation-related activities are as follows:

Activity	Unit Cost
Excavation and Stockpiling	$10 to $15 per ton
Dewatering, Water Treatment, and Water Disposal	$10 to $20 per ton
Backfilling and Compaction	$5 to $10 per ton

These costs assume that large volumes of soil are excavated (i.e., more than 10,000 tons) and does not include the cost to purchase soil to backfill excavated areas.

Screening Evaluation—Excavation of contaminated soil is prerequisite to any of the proposed ex situ treatment or disposal processes. Excavation is an effective means of reducing contaminant volume and decreasing potential long-term exposure to contaminants, although excavation introduces the potential for short-term exposure of workers. Excavation is likely to provide significant additional long-term protection of human health and the environment.

Calculations were performed to estimate the pumping rates required to dewater an excavation. Details of this effort are included in Appendix C. Dewatering rates are estimated at up to 90 gpm for the shallow unit and 300 to 350 gpm for the deep sand layer. Based on these estimated dewatering rates, it is impractical to dewater the sand layer for excavation of the shallow unit. In addition, calculations were performed to evaluate the depth to which an excavation can be completed into the shallow unit without resulting in heave or piping due to hydrostatic pressure in the sand unit. Based on these calculations, the maximum possible depth of excavation at the Quendall Terminals property is approximately 14 feet bgs (PacRim, 2000).

Focused excavation of DNAPL-contaminated soil could be used to limit potential migration of DNAPL to Lake Washington and reduce the long-term source of contaminants to groundwater. Excavation is retained for further consideration as a potential technology for removal of DNAPL-contaminated soil. Because excavation can only occur at a depth of less than 14 feet below grade, it is not anticipated that excavation will be widely applicable at the Quendall Terminals property.

Thermal Desorption

<u>Description of Technology</u>—Thermal desorption is a demonstrated technology for remediation of soil contaminated with a variety of organic compounds. During the process, volatile and semivolatile contaminants are separated from excavated soil through the use of air, heat, and mechanical agitation. Temperatures of 400°F to 1,000°F are used to volatilize contaminants from excavated soil, and the contaminant vapors are transferred to a gas treatment unit. Thermal oxidation is the most common and preferred gas treatment process, although other technologies such as carbon adsorption are also used. Thermal desorption results in a permanent reduction in contaminant volume, mobility, and toxicity. The process is often sufficiently effective to allow the treated soil to be used as backfill in the excavated areas.

Thermal desorption can be accomplished using onsite mobile units or at offsite fixed-base units. Onsite units require that sufficient space is available at the site for the treatment unit and for contaminated and clean soil stockpile areas. Feed rates to onsite units typically range from 20 to 90 tons per hour, and treatment costs range from $40 to $50 per ton, assuming large volumes of soil are being treated. Thermal desorption at an offsite facility would require an area for stockpiling contaminated soil, as well as an area for imported clean fill. Offsite treatment of contaminated soil also would require transport, likely via truck along public streets. As such, haul roads and traffic patterns would have to be established and maintained. The estimated cost for offsite treatment at the TPS facility in Tacoma, Washington, is $40 to $50 per ton, including transportation.

<u>Screening Evaluation</u>—Thermal desorption is a proven and cost-effective technology that is readily available and moderately simple to implement. The thermal desorption process results in a permanent reduction in contaminant volume, toxicity, and mobility. Onsite thermal desorption units can be used to eliminate the costs associated with transport of contaminated soil and clean fill to and from the site. Thermal desorption is often capable of achieving a sufficient reduction in contaminant concentration to allow the treated soil to

be used as backfill in the excavation areas, thereby limiting costs associated with purchase of imported clean fill materials. Thermal desorption is retained for further consideration.

Incineration

Description of Technology—Incineration is a demonstrated remediation technology for the treatment of soil containing organic contaminants. The incineration process uses high temperatures (1,600°F to 2,200°F) to volatilize and subsequently thermally oxidize organic contaminants. When properly operated, incineration can achieve greater than 99.99 percent destruction of organic contaminants. It can be performed onsite using permitted mobile incinerators or offsite at a permitted, commercial facility. Similar to thermal desorption, incineration requires excavation and stockpiling of contaminated soil, and stockpiling of clean fill materials. Incineration costs are highly dependent on the volume of material being treated, the contaminant type, permitting requirements, and the type of incinerator used. Typical costs range from $300 to $1,000 per ton.

Screening Evaluation—Incineration is similar to thermal desorption, but is a more aggressive treatment technology. Incineration is well demonstrated, generally readily available, and moderately simple to implement. Incineration can be performed using onsite or offsite treatment units. However, permits for operation of incineration units are becoming increasingly difficult to obtain. The incineration process leads to a permanent reduction in contaminant volume, toxicity, and mobility, and is generally more effective than thermal desorption, but is significantly more costly. Incineration is not retained for further consideration since thermal desorption is less costly and has been demonstrated to effectively treat the constituents of concern at this site.

Bioremediation (Landfarming)

Description of Technology—Bioremediation via landfarming is a demonstrated technology that has been widely used at wood treatment facilities to remediate soil contaminated with PAH compounds and creosote. During the landfarming process, contaminated soil is excavated and spread over a prepared treatment bed. Careful control of nutrient concentrations, moisture levels, and oxygen content is maintained in the treatment bed soil, accelerating microbial bio-oxidation of the organic contaminants. The soil is treated in shallow lifts, which are removed from the treatment bed once specified treatment goals have been achieved. The process has been reported to achieve contaminant destruction efficiencies ranging from 50 to 90 percent—achieving a permanent reduction in contaminant volume, mobility, and toxicity. Costs for landfarming typically range from $30 to $40 per yd3. Typically, 500 to 4,000 yd3 of soil can be treated per acre of treatment bed, over a treatment period of 6 months to 1 year.

Screening Evaluation—Landfarming bioremediation of organic contaminants leads to a permanent reduction in contaminant volume, toxicity, and mobility, thereby reducing the long-term potential exposure to site contaminants. The potential for short-term exposure of workers to the contaminants exists, however, throughout the excavation and landfarm treatment process. Bioremediation typically is not as effective as thermal treatment techniques, and is not significantly less costly than thermal desorption. More importantly, landfarming requires an extended treatment period (e.g., 6 months to 1 year) to achieve a significant reduction in contaminant concentration, and is thus incompatible with the desired remediation schedule for the Quendall Terminals site. Landfarming is not retained for further consideration.

Offsite Landfill Disposal

Description of Technology—Contaminated soil excavated from the Quendall Terminals site can be disposed in an appropriately permitted offsite landfill. These landfills are secure, lined facilities designed to contain contaminated materials and to prevent contact with human or ecological receptors, thereby providing long-term protection of human health and the environment. Landfill disposal does not reduce contaminant volume, toxicity, or mobility, and there is a potential for short-term exposure of workers to the contaminants during excavation and handling of the contaminated soil. Offsite landfill disposal of contaminated soil would require transport, likely via truck along public streets. As such, haul roads and traffic patterns would have to be established and maintained. Disposal costs at a Subtitle C landfill (for Dangerous Waste) range from $100 to $200 per ton, and at a Subtitle D landfill range from $30 to $50 per ton, including transportation.

Screening Evaluation—Offsite landfill disposal would reduce potential migration of soil contaminants and prevent exposure of human or ecological receptors to contaminated materials. Landfill disposal would not reduce contaminant volume, mobility, or toxicity. Landfill disposal would require offsite transport of contaminated soil and purchase and transport of clean fill materials, which would be more costly than onsite thermal desorption treatment. Offsite landfill disposal is retained for consideration as an alternate technology should ex situ treatment (e.g., thermal desorption) prove infeasible.

Soil Washing

Description of Technology—Soil washing is an ex situ remediation process designed to separate contaminants from excavated soil. Excavated soil is mixed with plain water or water containing a chemical additive. Additives such as surfactants or solvents are used to enhance contaminant solubility. Soil washing can be used to achieve one of two goals:

- Separate the fine particles from the excavated soil to minimize the amount of soil requiring treatment and/or offsite disposal (in general, most soil contaminants are associated with soil fine particles), or

- Dissolve the contaminant in the washing solution.

Separation of the fines can reduce the volume of soil requiring treatment or disposal, but does not in itself reduce the mobility or toxicity of the contaminant. Following contact with the soil, the wash solution is treated to remove the contaminants and, if applicable, recycle the chemical additive. Soil washing costs typically range from $120 to $200 per ton; however, due to the insoluble nature of the PAH contamination encountered, costs may be higher for soil at the Quendall Terminals site.

Screening Evaluation—Soil washing is often an effective means of reducing contaminant volume. However, the soil washing process is more costly and less effective than other treatment alternatives, such as thermal desorption or offsite landfill disposal. As a result, soil washing is typically limited to sites where minimization of contaminated soil volume is a high priority. Soil washing is not retained for further consideration.

Stabilization - Shallow Soil Mixing

Description of Technology—Stabilization involves adding chemical additives, such as cement or fly ash, to reduce the flux of contaminants from impacted soil due to leaching or groundwater dissolution. The stabilization technology can be implemented in situ or ex situ. The in-situ soil treatment technology involves micro-encapsulation of contaminated soil in a concrete matrix. This method was initially developed for civil engineering applications to provide additional bearing capacity for soft soil. The appropriate slurry or dry mix is injected directly into the soil under high pressure and mixed in situ with the contaminated soil by a tracked unit which provides rotary mixing. Soil is mixed with a single-blade auger or with a solid stem augers ranging from 3 to 12 feet in diameter. Mixing can be accomplished to depths exceeding 100 feet using this method.

Laboratory testing is required to demonstrate the effectiveness of the stabilization/solidification process, and to achieve the optimal mixing ratios for full-scale application. Costs for shallow (less than 40 feet) soil mixing range from $40 to $80 per cubic yard, depending on depth and the slurry mix required for the site, with placement rates typically 40 to 60 cubic yards per hour for each mixing rig.

The encapsulation of the contaminated soil reduces toxicity and mobility, but does not reduce contaminant volume. The encapsulated material also acts as a barrier to groundwater movement.

Screening Evaluation—Stabilization of contaminated soil has been demonstrated effective in reducing the mobility and leachability of hydrocarbons. A significant advantage to stabilization soil technologies is the elimination of the requirement for excavating and treating contaminated soil. This greatly reduces the exposure risk of site workers and nearby residents, eliminates the need for stockpile areas, loadout areas and heavy truck traffic on public roadways, and minimizes material handling costs. Stabilization is retained for further consideration.

Capping

Description of Technology—Capping technologies are designed to minimize direct human exposure to the contaminants and, in some cases, reduce contaminant mobility by isolating the affected soil in place. Caps can consist of a clean soil layer to provide a physical barrier to direct human contact with the affected soil, and/or a layer of impervious materials (e.g., asphalt) that provide a barrier to both direct exposure and infiltration to the affected soil. Buildings and similar structures constructed during site redevelopment can also serve as a cap. Capping is a containment technology, not a treatment process, and thus does not achieve a reduction in contaminant volume, mobility, or toxicity. Estimated costs for capping range from $1 to $3 per square foot, depending on the nature of the cap. These costs do not include the costs required for cap maintenance.

Screening Evaluation—Soil capping is an effective and relatively inexpensive means of reducing potential exposure to soil contaminants. A clean material cap of sufficient thickness (e.g., 2 to 3 feet) is applicable to the site to prevent dermal contact. Redevelopment structures, such as buildings and parking lots, would also serve as effective barriers to exposure to site soil contaminants. Maintenance of the cap would be required to ensure cap integrity and long-term effectiveness. Careful design and control of surface drainage systems and cap revegetation measures would be required to prevent cap erosion. Institutional controls would be required to ensure that future site activities do not interfere with the cap performance. Appropriate controls would include prescriptive measures for worker safety during site excavation or other construction-related activities potentially involving contact with soil contaminants beneath the cap. Additional measures would include deed restrictions requiring that following any disturbance, the cap be replaced or that another equally protective measure be taken. Capping is retained for further consideration.

Soil Flushing

Description of Technology—Soil flushing is an in situ soil remediation technology similar to soil washing. Soil flushing attempts to extract contaminants from soil by flushing the soil in situ with water or with water containing a chemical additive. The flushing solution is applied to the affected soil via well injection or surface infiltration, and the contaminant-bearing leachate is collected using extraction wells located downgradient of the treated soil zone. Once extracted, the leachate water is treated using established ex situ water treatment processes. Soil flushing, when combined with ex situ water treatment, results in a permanent reduction in contaminant volume. Soil flushing can potentially result in increased long-term mobility of residual contaminants, as contaminant solubility may be enhanced by remnant washing solution. Application of soil flushing technology is limited to sites with favorable hydrogeologic conditions that allow for efficient flushing of the contaminants from the soil and for complete recovery of the leachate solution. The presence of free-phase contamination (e.g., DNAPL) can substantially limit the effectiveness of soil flushing. The cost for soil flushing depends greatly on the composition of the wash solution and can range from $25 to $250 per cubic yard.

Screening Evaluation—The soil flushing process would result in a permanent reduction in contaminant volume. Soil flushing is an in situ remediation process, and thus eliminates the potential for worker exposure to soil contaminants due to excavation. However, the presence of DNAPL in the subsurface would significantly limit the effectiveness of soil flushing. The presence of nearby surface water would make hydraulic control difficult to demonstrate and relatively low permeability of shallow soil would make consistent application difficult. Soil flushing is not retained for further consideration.

In Situ Vitrification

Description of Technology—In situ vitrification is a soil remediation technology that involves placing electrodes into the ground and inducing an electric current to generate extremely high temperatures in the affected soil. The high temperatures cause the soil to melt, immobilizing inorganic contaminants by encapsulating them in a glass-like matrix and destroying organic contaminants via thermal oxidation. During the treatment of soil containing organic contaminants, such as the soil at the Quendall Terminals site, a hood placed over the treated area is often required to control off-gases released during the treatment process. The vitrification process reduces the volume, mobility, and toxicity of organic contaminants. Vitrification is a complex, high-energy technology that requires a high degree of expertise and training. As such, costs for in situ vitrification are high, typically on the order of $700 per ton.

Screening Evaluation—In situ vitrification would lead to a permanent reduction in contaminant volume, toxicity, and mobility, and would limit the potential for long-term exposure to site contaminants. As treatment is performed in situ, there is no potential for worker exposure to contaminants due to soil excavation. However, off-gases produced from vitrification can be potentially harmful if proper control measures are not implemented.

Converting soil to a solid, glass-like mass during vitrification could limit potential future site uses and redevelopment. In addition, in situ vitrification is cost-prohibitive. In situ vitrification is not retained for further consideration.

Soil Vapor Extraction

Description of Technology—Soil vapor extraction (SVE) is an in situ remediation process designed for the removal of volatile or semivolatile contaminants from unsaturated soil. The SVE process involves installing air extraction wells in vadose zone soil, and applying a vacuum to induce the flow of air through the soil. Volatile contaminants are stripped from the soil matrix with the moving air, and the extracted air is then treated ex situ using established gas treatment processes (e.g., via granular activated carbon [GAC] adsorption). In some cases, air injection wells are required in addition to the air extraction wells to enhance air flow and increase contaminant removal efficiency. Air flow, and thus SVE efficiency, is limited by low permeability strata and high soil moisture content. SVE permanently reduces the contaminant volume and, depending on the gas treatment process, also reduces the mobility and toxicity of extracted contaminants. A typical cost for SVE, excluding the cost for treatment of off-gases, is $50 per ton.

Screening Evaluation—SVE, when combined with gas treatment, would produce a permanent reduction in contaminant volume. However, the SVE process would be highly inefficient at the Quendall Terminals site because of the relatively shallow water table and the presence of DNAPL, and would not likely be capable of achieving the site RAOs. SVE is not retained for further consideration.

Bioventing

Description of Technology—Bioventing is a demonstrated treatment process that is similar to SVE. Unlike SVE, which strips the contaminants from the aquifer matrix using high air flow rates, bioventing uses lower air flow rates with the goal of stimulating the bio-oxidation of the contaminants by delivering oxygen (by the induced air flow) to naturally occurring microorganisms. Bio-oxidation reduces contaminant volume, mobility, and toxicity. Unlike SVE, bioventing is not limited to volatile and semivolatile contaminants, and is applicable to any other organic contaminants that are susceptible to aerobic bio-oxidation. Aboveground off-gas treatment is often required for bioventing, and air flow can be limited by low permeability strata and soil with excessive moisture. Too little soil moisture can also limit bioventing efficiency by limiting biological growth. Typical costs for bioventing range from $10 to $50 per cubic yards of soil.

Screening Evaluation—Similar to SVE, bioventing would produce a permanent reduction in contaminant mass, but is not likely to achieve the

RAOs established for the Quendall Terminals site. Bioventing is not retained for further consideration.

5.2 Technologies for Remediation of Groundwater

This section identifies and screens technologies potentially applicable for remediation of contaminated groundwater at the Quendall Terminals site. As discussed previously, contaminants detected in groundwater at the site include PAH compounds, benzene, and DNAPL. The remediation technologies presented in this section include natural attenuation, groundwater extraction, impermeable barrier wall, passive treatment wall, DNAPL recovery trenches, and biosparging. Brief descriptions of each of these alternative technologies are presented along with a discussion of their implications for the Quendall Terminals site. The technologies presented are screened in terms of their ability to cost-effectively achieve the site RAOs through the destruction and/or containment of the site groundwater contaminants.

Natural Attenuation

Description of Technology—Natural attenuation refers to naturally occurring chemical, physical, and biological processes that contain or degrade environmental contaminants. Chemical adsorption to aquifer materials and microbial biodegradation of organic contaminants are common examples of natural processes that may reduce availability of a contaminant or degrade it to less toxic or nontoxic constituents. Natural attenuation requires that specific conditions (e.g., pH, abundant dissolved oxygen) exist in the subsurface. Demonstration of natural attenuation processes requires monitoring of contaminants and other indicator compounds (e.g., biodegradation products, dissolved oxygen, redox potential). This monitoring often must be supported by computational modeling and/or laboratory demonstrations. The cost associated with natural attenuation is related to the cost of these demonstration activities.

Screening Evaluation—Natural attenuation processes have been demonstrated to be sufficiently effective to meet remediation goals at several sites in the United States. However, given the extent and nature of the contamination at the Quendall Terminals site, and the close proximity of the groundwater contaminants to Lake Washington, it is uncertain whether natural attenuation processes are sufficiently effective to meet the site RAOs. Natural attenuation is retained for consideration, although it will not be applicable until source removal or treatment activities have occurred.

Groundwater Extraction

Description of Technology—Groundwater extraction is a remediation technology that involves the extraction of contaminated groundwater, typically through the use of groundwater extraction wells, followed by ex situ treatment using established water treatment processes. Treated water would be discharged to the Renton POTW or to surface water under an NPDES permit. Groundwater extraction together with ex situ treatment is commonly referred to as "pump and treat." Groundwater extraction is generally used to hydraulically control the contaminated groundwater and prevent its further migration.

Pump and treat would reduce contaminant volume, toxicity, and mobility; however, it does not effectively remove contaminants from the subsurface. Pump and treat relies on either the physical removal of NAPL or the removal of dissolved constituents along with groundwater. When pump and treat begins, some NAPL is initially removable. Given the low mobility of NAPL in soil and the relative productivity of the aquifer present at the site, however, the direct removal of NAPL does not typically continue and very little or no NAPL would be recovered after this initial period. Because the solubility of the NAPL constituents is so low, removal through the dissolved phase is very slow and DNAPL at the Quendall Terminals site would act as a long-term source of contaminants to groundwater. As a result, this remediation technology would involve long-term operation and maintenance costs. Installing groundwater extraction wells costs approximately $25,000 per well with additional costs incurred to purchase and operate a water treatment system. Annual operation and maintenance costs for a pump-and-treat system are estimated at $250,000.

Screening Evaluation—Groundwater extraction is a highly inefficient means of reducing subsurface contaminant volume, particularly when long-term sources of groundwater contaminants such as DNAPL are present, and has rarely been shown to be capable of achieving site RAOs in a reasonable time frame. The likelihood of residual DNAPL being present following implementation of remedial activities would limit pump-and-treat remediation efficiency. Groundwater extraction is retained for consideration as a containment approach, but will not be considered for source removal and treatment.

Impermeable Barrier Wall

Description of Technology—Impermeable barrier walls, such as slurry walls or sheet piling, can be installed along a vertical plane in the subsurface to provide a barrier to contaminant flow. Slurry walls are installed by excavating a trench and backfilling the trench with a soil-bentonite or soil-cement mixture, producing a barrier with hydraulic conductivity of 10^{-5} to 10^{-7} cm/sec. Slurry walls cost $7 to $12 per square foot to construct. Treatment of contaminated soil excavated during the slurry wall installation process would add additional cost. Sheet pile barrier walls are installed by driving interlinking steel sheet piling into the subsurface. Permeability of sheet pile barriers is limited to leakage through the interlocking joints, which are often sealed (e.g., via grout injection). Unlike slurry walls, sheet pile walls can also be installed offshore in Lake Washington sediments. Sheet pile installation costs between $20 and $30 per square foot.

Screening Evaluation—At the Quendall Terminals site, low permeability barrier walls could provide a barrier to direct groundwater and potential DNAPL discharge to Lake Washington. Impermeable barrier (or containment) wall technology has been demonstrated to be an effective means of reducing contaminant migration. A containment wall placed adjacent to the lake shoreline to a depth of 25 to 30 feet would slow the flow of groundwater contaminants offsite and reduce the potential for DNAPL migration to the lake. Offshore installation of sheet piling to create a vertical barrier to lateral DNAPL flow could be an effective means of decreasing the potential for DNAPL migration to Lake Washington. A containment wall is retained for further consideration.

Passive Treatment Wall

Description of Technology—Passive treatment wall technology involves the installation of a permeable wall of reactive material along a vertical plane to intercept contaminant flow. As the contaminated groundwater passes through the reactive material, the contaminants are attenuated by chemical or biological reaction within the wall. Impermeable barrier walls are often used to direct contaminated water through the passive treatment wall. Peat moss and GAC are common reactive materials used for treating nonchlorinated organics such as those found at the Quendall Terminals site. The cost of installing a passive treatment wall depends on the physical dimensions of the wall and the reactive material used, and as such, is highly site-specific. Operation and maintenance costs include costs of maintaining permeability reduction problems caused by precipitate formation within the wall, and for periodic replacement of the reactive material. The presence of DNAPL may significantly impair the functional ability of the passive treatment wall.

Screening Evaluation—Passive treatment wall technology has been demonstrated at some sites as an effective in situ process for reducing contaminant volume and/or preventing offsite contaminant migration. However, the presence of DNAPL in the subsurface at the Quendall Terminals site demonstrated that a passive treatment wall is not likely to be effective in those areas. Passive treatment wall technology is retained for further consideration in areas where DNAPL is not present.

DNAPL Recovery Trenches

Description of Technology—DNAPL recovery trenches are subsurface trenches installed to intercept and recover DNAPL plumes. Installation of the recovery trenches involves excavating a trench downgradient of the DNAPL plume, placing a perforated collection line at the bottom of the trench, and backfilling the trench with coarse material (e.g., gravel). As DNAPL intercepts the trench, it preferentially migrates down the permeable backfill material to the collection line, and is pumped to the surface using a recovery sump. The DNAPL is stored at the surface and periodically transported to an offsite facility for treatment, reuse, or disposal. This process results in a permanent decrease in contaminant volume, toxicity, and mobility. Handling recovered DNAPL can result in potential short-term exposure of workers to site contaminants. Typical costs for installing DNAPL recovery trenches range from $30 to $50 per square foot. Additional cost would be incurred for pumping equipment, piping, and operations and maintenance

Screening Evaluation—DNAPL recovery trenches are not effective at removing a significant amount of contaminant mass and can result in the spreading of contamination at greater depths. As installation of the trenches would involve excavation, localized groundwater dewatering may be required during trench installation, and the pumped groundwater would likely require treatment. Furthermore, excavation of contaminated soil during trenching would result in a short-term potential for worker exposure to contaminants, and contaminated soil would likely require dewatering with soil and groundwater treatment. DNAPL recovery trenches are not retained for further consideration.

Biosparging

Description of Technology—Biosparging is an in situ remediation technology designed to stimulate the aerobic bio-oxidation of organic groundwater contaminants by naturally occurring subsurface microorganisms. The process involves injecting compressed air into wells screened below the water table, thereby increasing the oxygen concentration in the groundwater and overlying unsaturated zone, and stimulating aerobic bio-oxidation of organic contaminants. The sparging process can volatilize (or strip) volatile and semi-volatile contaminants from groundwater, causing the contaminants to migrate to the overlying unsaturated zone. Biosparging permanently reduces contaminant volume, toxicity, and mobility.

Screening Evaluation—Biosparging is an effective means of containing groundwater contaminants at the Quendall Terminals site. A treatability study (RETEC 1997) demonstrated that an increase in oxygen can successfully degrade PAH compounds and benzene. Biosparging would result in a permanent reduction in volume, toxicity, and mobility of groundwater contaminants. Furthermore, if the induced bio-oxidation rate of the contaminants is sufficiently rapid, biosparging could prevent migration of groundwater contaminants to Lake Washington. Biosparging is retained for further consideration.

5.3 Technologies for Remediation of Sediment

This section identifies and screens technologies potentially applicable for remediating contaminated sediment and sediment wood waste at the Quendall Terminals site. As discussed in this report, PAH and benzene contamination and wood waste have been identified in Lake Washington sediment immediately adjacent to the Quendall Terminals property. In addition, DNAPL associated with the Quendall source area has been identified at approximate depths of 5 ft and 15 ft below the mud line, respectively.

The remediation technologies presented in this section include natural recovery, dredge and removal, upland treatment (e.g., thermal desorption, incineration, bioremediation, and landfill disposal), capping, and a nearshore containment facility. Brief descriptions of each of these alternative technologies are presented along with a discussion of implementation implications for the Quendall Terminals site.

Natural Recovery

Description of Technology—Natural recovery refers to naturally occurring chemical, physical, and biological processes that function to contain or degrade environmental contaminants in sediments. Sedimentation and microbial biodegradation are examples of natural processes that may reduce availability of a contaminant or degrade it to less toxic or nontoxic constituents. Natural recovery requires that specific conditions (e.g., pH, abundant dissolved oxygen) exist in the sediments. Demonstration of natural recovery processes requires monitoring of contaminants and other indicator compounds (e.g., biodegradation products, dissolved oxygen, redox). Monitoring often must be supported by computational modeling and/or laboratory demonstrations. The cost of natural recovery is related to the cost of these demonstration activities.

Screening Evaluation—It is unlikely that natural recovery processes would be sufficiently protective at the Quendall Terminals site without additional remedial measures. As a result, natural recovery is retained for further consideration, but only to address residual impacts after source removal has occurred.

Dredge and Removal

Description of Technology—Dredge and removal involves the use of mechanical or hydraulic dredging technologies to bring contaminated sediments to the surface for ex situ treatment, recycling, or disposal. Dredged sediments would be transported upland and dewatered, and the water produced would be treated. The dredge and removal of sediments process, when combined with ex situ treatment, reduces contaminant volume, toxicity, and mobility. During the process, there is a potential for short-term exposure of workers to contaminants.

Various dredging technologies are potentially applicable at the Quendall Terminals site. Hydraulic dredges vacuum sediments in a slurry through a pipeline to the surface. Mechanical dredges collect discrete volumes of contaminated sediments in a suspended bucket. Land-based excavating techniques (e.g., backhoe excavation) are potentially applicable for removal of nearshore or shallow sediments. Unit costs for dredge and removal of contaminated sediment range from $40 to $60 per yd3 of dredged material. Dredging of non-contaminated sediments, such as the less than 50 percent wood waste zones, is considerably less costly ($8 to $12 per yd3) as re-suspension and loss of contaminants is of less concern.

Screening Evaluation—Dredging and removal technologies would be required for any sediment remediation alternative that involves ex situ treatment. These approaches are the only technologies considered that would produce a permanent reduction in contaminant volume, toxicity, and mobility. The dredging process would increase potential exposure of workers to site contaminants. Following dredging, sediments would be transported upland, dewatered, treated, recycled (i.e., reuse of wood waste material), or disposed of at an offsite landfill. The water produced during dewatering would likely require treatment prior to disposal in the sanitary sewer or discharge back to Lake Washington. Some of the dredged areas would require backfilling with clean materials or, if applicable, with treated sediments. Dredging and removal technologies are retained for further consideration.

Upland Treatment

Description of Technology—Upland treatment refers to the collection of established treatment technologies that can be used to treat contaminated sediments dredged and removed from the lake. These technologies include, but are not limited to treatment technologies presented in Section 5.1 of this report for ex situ treatment of excavated soil. These technologies include thermal desorption, incineration, bioremediation (landfarming), and landfill disposal.

Screening Evaluation—Upland treatment of the contaminated sediment would eliminate the costs associated with transport of contaminated soil and clean fill to and from the site. As described in Section 3.5.1.2, onsite thermal desorption is retained as an ex situ treatment process for the Quendall Terminals site. Landfill disposal is also retained as an alternate technology.

Capping

Description of Technology— Sediment capping technologies are appropriate for isolating impacted sediment from aquatic receptors. The sediment cap would require placement of clean material to a thickness of at least 1 foot to isolate contaminants from the bioactive zone. Amendments, such as GAC, may also be considered to reduce the flux of contaminants to surface water.

There is a variety of capping placement methods either used or considered elsewhere (Palermo et al., 1995). The methods include hydraulic pipeline delivery to either a floating spreader box or submerged diffuser; dozing, clamming or washing of barged capping materials to settle through the water column; distribution by controlled discharge from hopper barges; mechanically-fed tremie to the bottom; high-pressure spraying (monitoring) of a hydraulic sediment-water slurry across the water surface. Important factors in selecting the cap placement method is to assure minimum capping thickness over the entire remedial area, limit resuspension and loss of contaminated sediment to the water column, and prevent mixing of the contaminated sediment into the emerging cap layer. Experience elsewhere has confirmed that allowing the capping materials to settle through the water column rather than impact the bottom as a dumped mass or density driven hydraulic flow will tend to satisfy these requirements. Costs for cap placement range between $8 and $14 per cubic yard.

Screening Evaluation—Placement of a clean sediment cap is a demonstrated technology for reducing exposure. Based on considerations presented in the Sediment Memorandum (RETEC, 1997), the clamshell placement method was judged to be the best method to more reliably achieve the required accurate and consistent placement of a cap with minimal resuspension and loss of contaminated sediments form the lake bottom. Sediment capping is retained for further consideration.

Nearshore Containment Facility

Description of Technology—A nearshore containment facility involves the construction of a containment facility immediately adjacent to the existing shoreline. A containment wall is placed along the desired outer limit of the facility, and the area between the wall and the shoreline is filled with excavated contaminated sediment or soil, or with clean fill. The area ouside the wall could be filled and graded to provide suitable aquatic habitat. At the Quendall Terminals site, a nearshore containment facility could be designed as a disposal facility for contaminated sediment and as a cover for all or most of the offshore DNAPL identified at the site. Such a facility would not reduce contaminant volume, toxicity, or mobility, but would restrict potential migration of sediment contaminants and DNAPL to the lake. It would also reduce long-term potential for exposure to the contaminants. The cost of a nearshore containment facility would include the cost of barrier wall construction and dredging and placement of soil within the facility. Additional costs would include those associated with mitigation for shoreline impacts, wetland replacement, and lake infilling and habitat destruction.

Screening Evaluation—A nearshore containment facility would be an effective means of containing contaminated sediments and wood waste, and would provide a barrier to potential DNAPL seepage into Lake Washington. On the other hand, the facility would not reduce contaminant volume, toxicity, or mobility, and would potentially expose workers to contaminants during excavation and during placement of contaminated sediments within the facility. Furthermore, construction of the facility would require substantial mitigative action. The nearshore containment facility is retained for further consideration, but is anticipated to be administratively complex to implement.

5.4 Summary of Screening-Level Evaluation

Tables 5-1 through 5-3 summarize the results of the screening evaluation of remedial technologies. They also list media-specific technologies that are retained for consideration during the development of the proposed cleanup action plan for the Quendall Terminals site.

5.4.1 Institutional Controls

Institutional controls, such as deed and water use restrictions, are an essential part of most remediation efforts. Institutional controls are designed to provide assurance that human health and the environment are protected from residual subsurface contamination left in place following implementation of remedial measures. Institutional control programs for a given site would vary in breadth and intensity, depending on the remedial action selected.

5.4.2 Compliance Monitoring

Compliance monitoring is required for all remediation efforts. Postremedial sampling of soil, groundwater, and sediment is required to ensure that remedial measures perform adequately and protect human health and the environment and to confirm that site RAOs have been meet. Monitoring requirements would vary in intensity and duration, depending on the cleanup action selected.

Tables

Table 4-5 List of Groundwater Cleanup Levels (μg/L)

Contaminant of Concern	MCL (EPA, 1996)	MTCA Method A Groundwater (WAC 173-340)	MTCA Method B Groundwater[b] (WAC 173-340)	MTCA Method B Surface Water[b] (WAC 173-340)	Fresh Water Quality Criteria/Standards (40 CFR 131)[c]		Estimated Quantitation Limit (SW-846, Nov. 1992)	Practical Quantitation Limit[d]	Selected Cleanup Level
					Acute/ Chronic	Human Consumption of Organisms			
Benzene	—	—	—	43	—	—	—	—	43
Naphthalene	—	—	320	9,880	—	—	10	0.01	9,880
Acenaphthylene	—	—	—	—	—	—	10	0.01	—
Acenaphthene	—	—	960	643	—	—	10	0.01	643
Fluorene	—	—	640	3,460	—	14,000	10	0.01	3,460
Phenanthrene	—	—	—	—	—	—	10	0.01	—
Anthracene	—	—	4,800	25,900	—	110,000	10	0.01	25,900
Fluoranthene	—	—	640	90.2	—	370	10	0.01	90.2
Pyrene	—	—	480	2,590	—	11,000	10	0.01	2,590
Benzo(a)anthracene	—	0.1 [a]	0.012	0.0296	—	0.031	10	0.01	.0296
Chrysene	—	0.1 [a]	0.012	0.0296	—	0.031	10	0.01	.0296
Benzo(b)fluoranthene	—	0.1 [a]	0.012	0.0296	—	0.031	10	0.01	.0296
Benzo(k)fluoranthene	—	0.1 [a]	0.012	0.0296	—	0.031	10	0.01	.0296
Benzo(a)pyrene	0.2	0.1 [a]	0.012	0.0296	—	0.031	10	0.01	.0296
Dibenzo(a,h)anthracene	—	0.1 [a]	0.012	0.0296	—	0.031	10	0.01	.0296
Benzo(g,h,i)perylene	—	—	—	—	—	—	10	0.01	—
Indeno(1,2,3-cd)pyrene	—	0.1 [a]	0.012	0.0296	—	0.031	10	0.01	.0296
Pentachlorophenol	—	—	0.729	4.91	20/7.9 [e]	8.2	50	—	4.91

NOTES:

a Value for carcinogenic PAHs.
b Values obtained from MTCA Cleanup Levels and Risk Calculations (CLARC II) update.
c AWQC, EPA, 1997. Human health (10^{-6} risk for carcinogens) for consumption of organisms only.
d PQL estimated based on a survey of local laboratories using EPA Method 8270 SIM-PRO.
e Pentachlorophenol chronic criteria based on pH-dependent formula (exp(1.005(pH)-5.290)) at pH 7.8.

Table 4-6 List of Soil Cleanup Levels

Contaminant of Concern	MTCA Method B Direct Contact [a] (mg/kg)	100 × MTCA Method B Groundwater [a] (mg/kg)
Acenaphthene	4,800	96
Acenaphthylene	—	—
Anthracene	24,000	480
Benzene	34.5	4.3
Benzo(a)anthracene	0.137	0.0012
Benzo(a)pyrene	0.137	0.02
Benzo(b)fluoranthene	0.137	0.0012
Benzo(g,h,i)perylene	—	—
Benzo(k)fluoranthene	0.137	0.0012
Chrysene	0.137	0.0012
Dibenzo(a,h)anthracene	0.137	0.0012
Fluoranthene	3,200	64
Fluorene	3,200	64
Indeno(1,2,3,cd)pyrene	0.137	0.0012
Naphthalene	3,200	32
Pentachlorophenol	8.33	0.1
Phenanthrene	—	—
Pyrene	2,400	48

NOTES:

a MTCA CLARC II Update, February 1996.

Table 5-1 Summary of Remediation Technologies for Soil

Technology	Results of Screening	Screening Criteria		
		Effectiveness	Cost	Implementability
Excavation	Retained	Effective for limiting potential long-term exposure to site contaminants Potential short-term exposure of workers to contaminants	High	Well demonstrated technology Complete contaminant removal technically complicated and costly
Thermal Desorption	Retained	Effective for reducing contaminant volume	High	Can be implemented onsite using readily available, mobile treatment units
Incineration	Retained	Effective for reducing contaminant volume	High	Can be implemented onsite using mobile treatment units Permitting often difficult
Bioremediation (Landfarming)	Not Retained	Moderately effective at reducing contaminant volume Not as effective as thermal treatment	Moderate	Requires construction of onsite treatment facility Long term treatment period required
Offsite Landfill Disposal	Retained	Effective for reducing potential long-term exposure to site contaminants	Moderate to high	Requires offsite transport of contaminated soils and purchase of clean fill material

Table 5-1 continued

Soil Washing	Not Retained	Potentially effective for reducing volume of soil requiring treatment Not as effective as thermal treatment	High	Demonstrated technology Operation requires expertise
Stabilization- Shallow Soil Mixing	Retained	Effective in reducing the mobility and leachability of hydrocarbons	Moderate	Demonstrated technology Easy to implement with appropriate additive
Capping	Retained	Effective for reducing potential exposure to site contaminants	Low	Easy to implement
Soil Flushing	Not Retained	DNAPL likely to inhibit performance	Moderate	Moderately easy to implement
In Situ Vitrification	Not Retained	Effective for reducing contaminant volume Can potentially limit future site development	High	Requires significant operational expertise
Soil Vapor Extraction	Not Retained	DNAPL likely to inhibit effectiveness for reducing soil contaminant concentrations Potentially effective for controlling off gases produced by groundwater biosparging	Low	Demonstrated technology that is easy to implement and maintain
Bioventing	Not Retained	DNAPL likely to inhibit effectiveness for reducing soil contaminant Potentially effective for controlling off gases produced by groundwater biosparging	Low	Demonstrated technology that is easy to implement and maintain

Table 5-2 Summary of Remedial Technologies for Groundwater

Technology	Results of Screening	Screening Criteria		
		Effectiveness	**Cost**	**Implementability**
Groundwater Extraction	Not Retained	Ineffective for reducing contaminant volume	High	Easy to implement and maintain Long-term operation required
Hydraulic Control	Not Retained	Effective for preventing offsite migration of groundwater contaminants	Moderate	Easy to implement and maintain Long-term operation required
Natural Attenuation	Not Retained	Unlikely to be sufficient to meet RAOs	Low	Naturally occurring process
Impermeable Barrier Wall	Retained	Effective for limiting migration of groundwater contaminants and DNAPL to Lake Washington	Moderate	Demonstrated and readily available technology for containment
Passive Treatment Wall	Not Retained	Unlikely to be sufficient to meet RAOs	High	Demonstrated and readily available technology
DNAPL Recovery Trench	Retained	Effective for limiting offsite migration of upland DNAPL	Moderate	Simple technology that is easy to implement
Biosparging	Retained	Effective for limiting offsite migration of groundwater contaminants May require addition of SVE or bioventing to control off gases May require addition of hydraulic control to meet RAOs	Moderate	Demonstrated and readily available technology

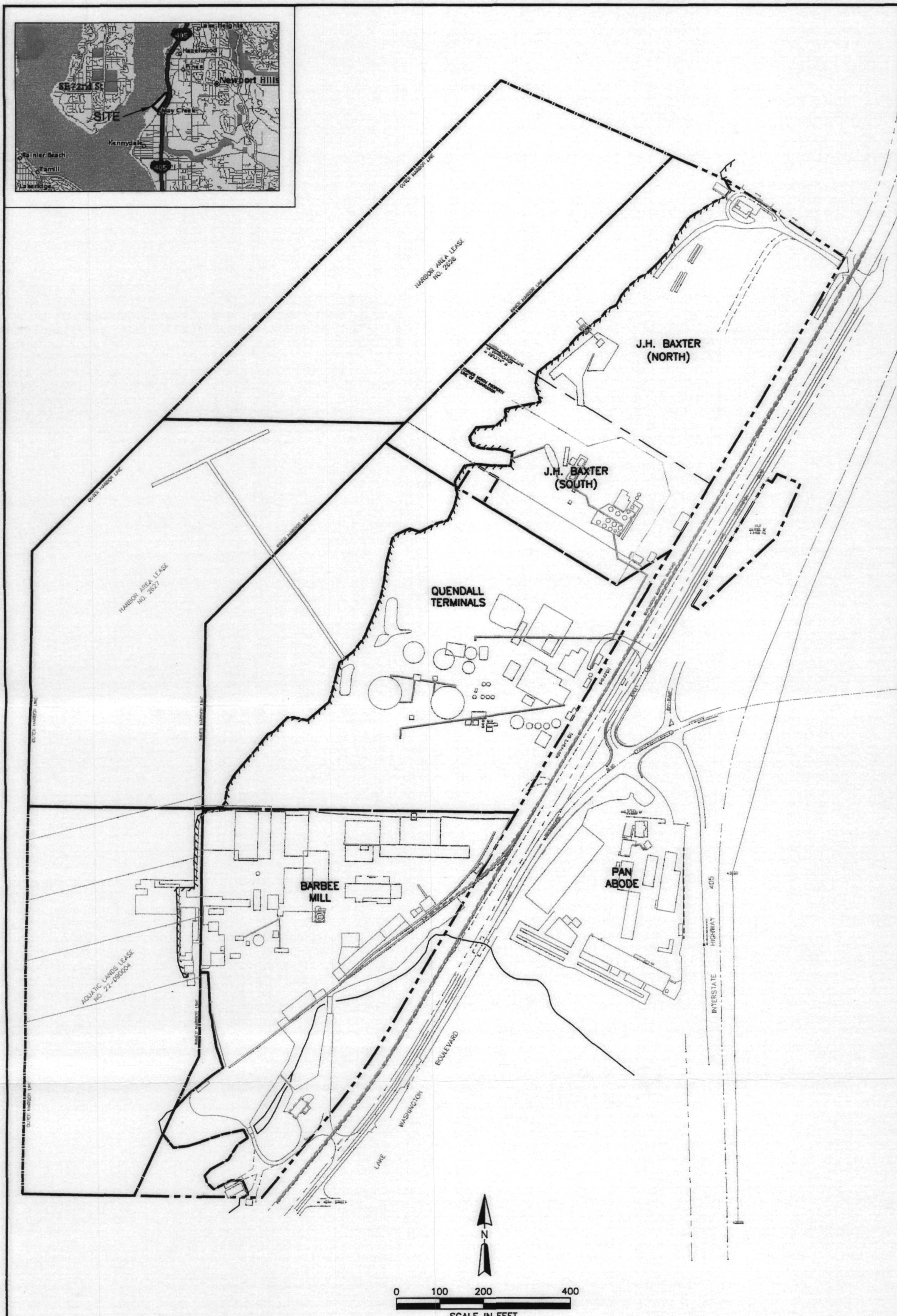
Table 5-3 Summary of Remediation Technologies for Sediment

Technology	Result of Screening	Screening Criteria		
		Effectiveness	Cost	Implementability
Natural Recovery	Retained	Effective for reducing potential long-term exposure to site contaminants when combined with other remedial activities	Low	Naturally occurring process
Dredge and Removal	Retained	Effective for limiting potential long-term exposure to site contaminants Potential short-term exposure of workers to contaminants	Moderate	Demonstrated and readily available technology
Thermal Desorption	Retained	Effective for reducing contaminant volume	Moderate	Can be implemented onsite using readily available, mobile treatment units
Incineration	Retained	Effective for reducing contaminant volume	High	Can be implemented onsite using mobile treatment units Permitting often difficult
Bioremediation (Landfarming)	Not Retained	Moderately effective for reducing contaminant volume Not as effective as thermal treatment	Moderate	Requires construction of onsite treatment facility Long treatment period required

Table 5.3 continued

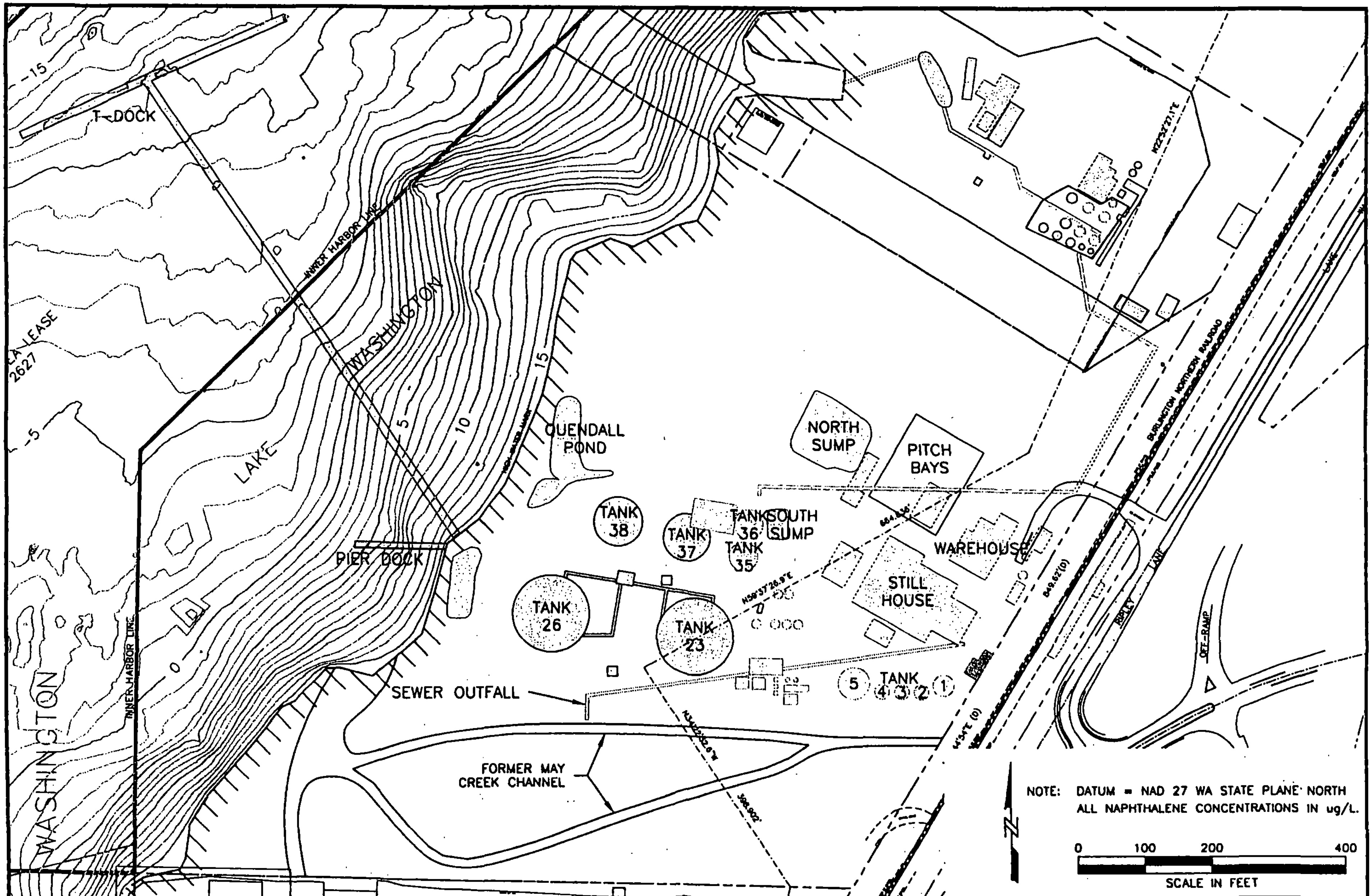
Offsite Landfill Disposal	Retained	Effective for reducing potential long-term exposure to site contaminants	Moderate to high	Required offsite transport of contaminated sediments and purchase of clean fill material
Nearshore Containment Facility	Not Retained	Effective for limiting potential long-term exposure to site contaminants Requires significant mitigation efforts	Moderate to high	Complicated by in-lake construction
Nearshore Trap	Retained	Effective for limiting potential long-term exposure to site contaminants	Moderate to high	Complicated by in-lake construction
Capping	Retained	Effective for reducing potential long-term exposure to site contaminants Effective for reducing DNAPL migration to the Lake and Lake sediments	Low	Demonstrated and readily available technology

Figures



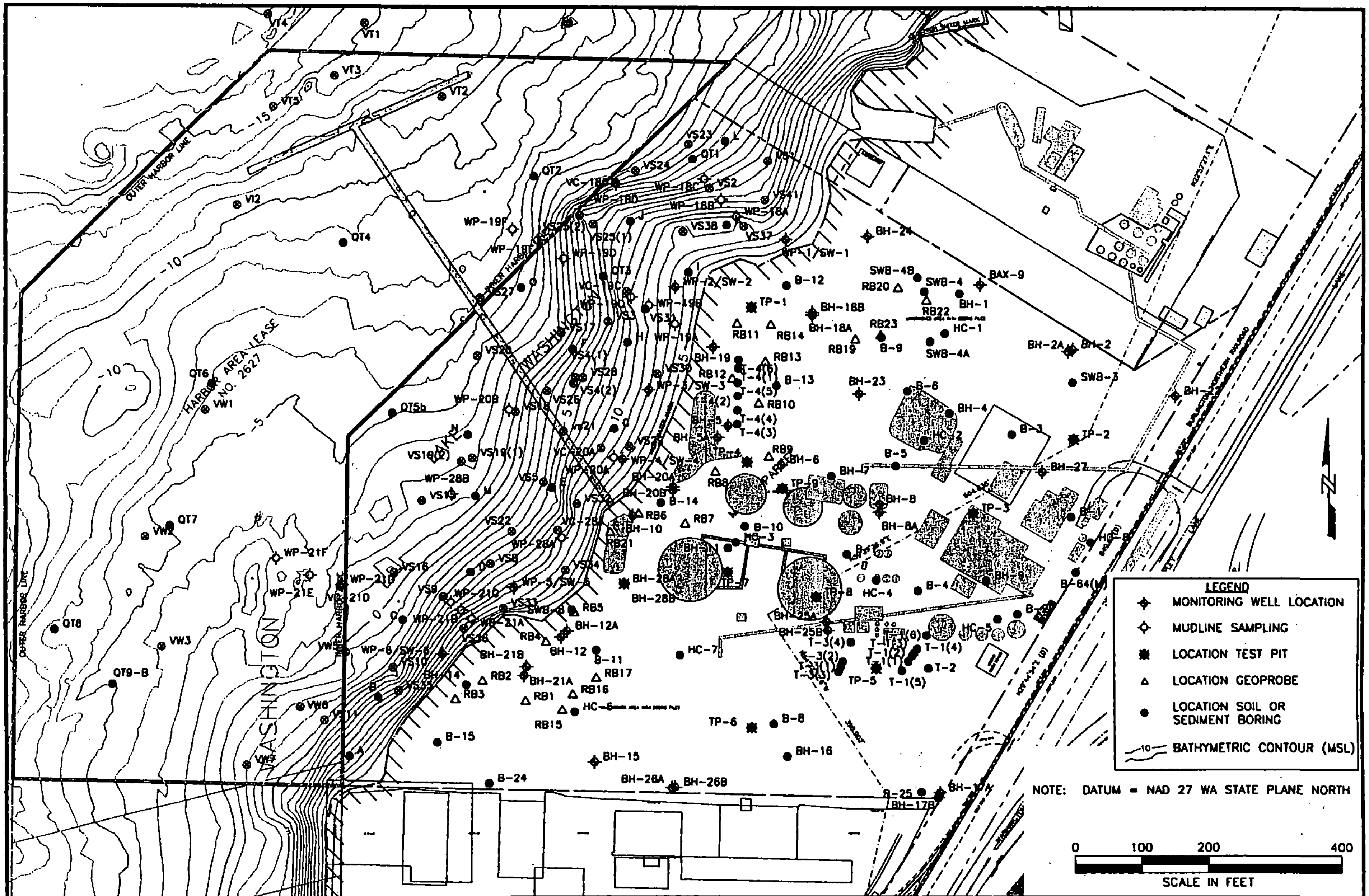
ThermoRetec

QUENDALL TERMINALS JAGCO-02438-770			ADJACENT PROPERTIES SITE MAP
DATE: 07/20/01	DRWN: N.S.	FILE: 2438S383	FIGURE 1-1



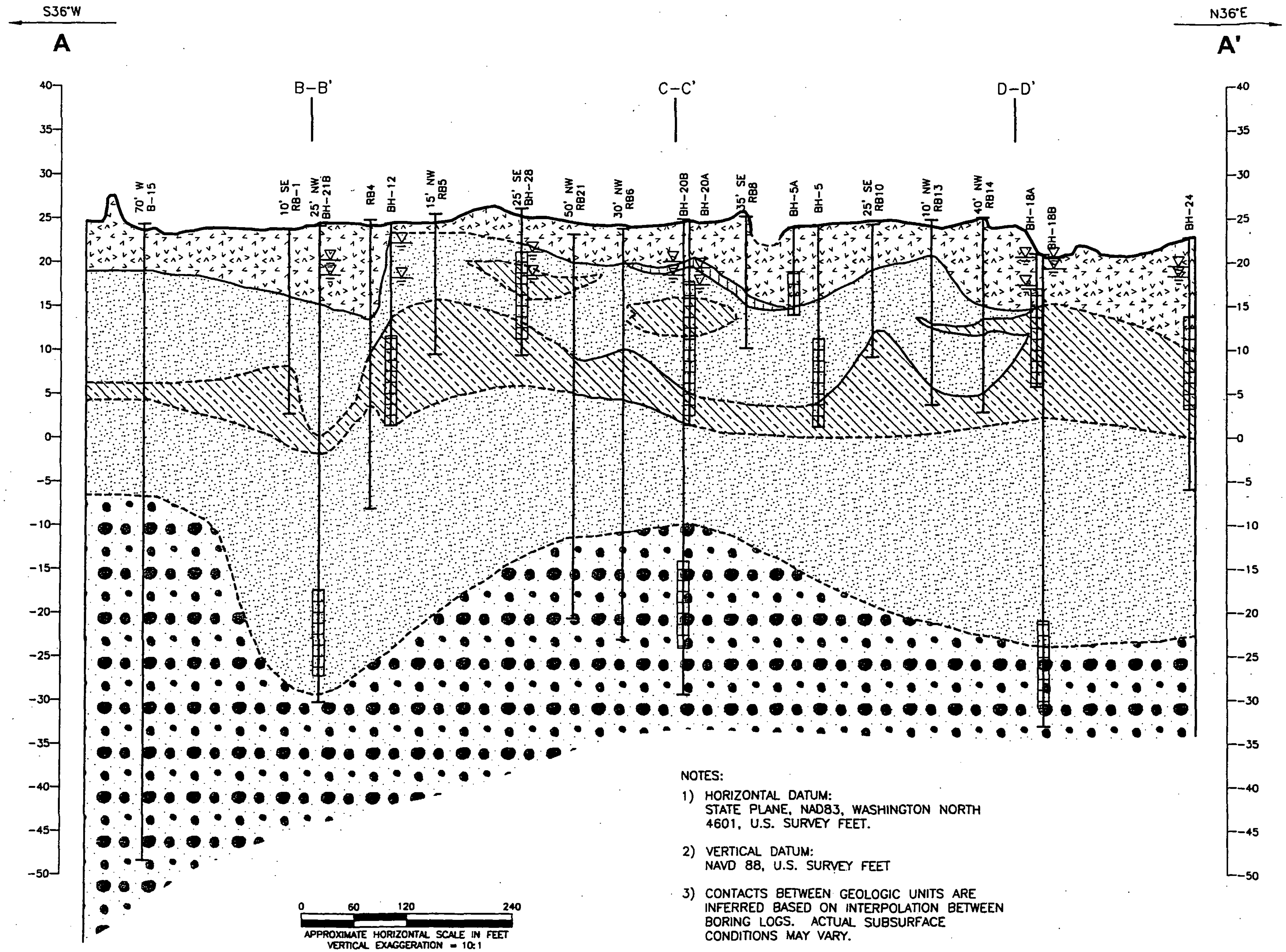
ThermoRetec

QUENDALL TERMINALS			HISTORIC FEATURES MAP
JAGCO-02438-770			
DATE: 07/20/01	DRWN: N.S.	FILE: 2438S384	FIGURE 1-2



ThermoRetec

QUENDALL TERMINALS	SAMPLING LOCATIONS
JAGCO-02438-770	
DATE: 06/28/01 · DRWN: N.S. · FILE: 2438S366	FIGURE 1-3



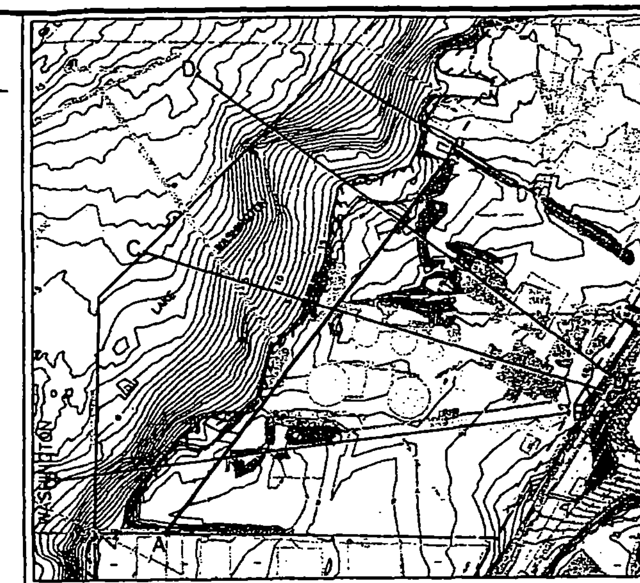
NOTES:

1) HORIZONTAL DATUM:
STATE PLANE, NAD83, WASHINGTON NORTH
4601, U.S. SURVEY FEET.

2) VERTICAL DATUM:
NAVD 88, U.S. SURVEY FEET

3) CONTACTS BETWEEN GEOLOGIC UNITS ARE INFERRED BASED ON INTERPOLATION BETWEEN BORING LOGS. ACTUAL SUBSURFACE CONDITIONS MAY VARY.

4) GROUNDWATER ELEVATIONS REPRESENT HIGH AND LOW GAUGING LEVELS FOR WELLS ONLY.



250 0 500
SCALE IN FEET

NOTE: DATUM = NAD 27 WA STATE PLANE NORTH

LEGEND

- FILL
- WOOD
- SILTY SAND
- CLAY or SANDY CLAY
- SAND OR GRAVELLY SAND
- PEAT
- GRAVEL OR SANDY GRAVEL
- WATER LEVEL
- SCREEN
- CONTACT W/ CERTAINTY
- UNCERTAIN CONTACT
- 35' SE RB8 BORING LOCATION AND OFFSET

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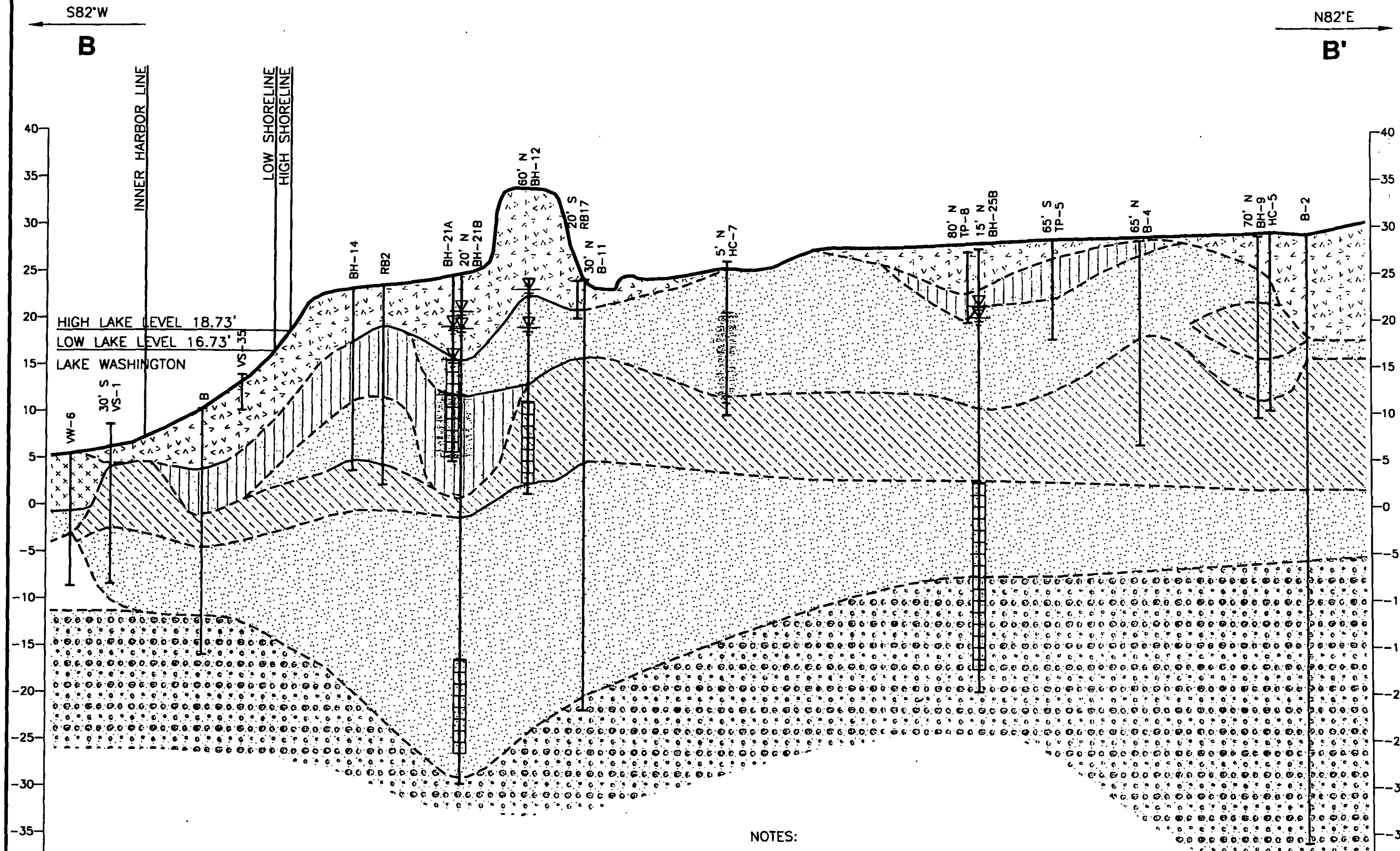
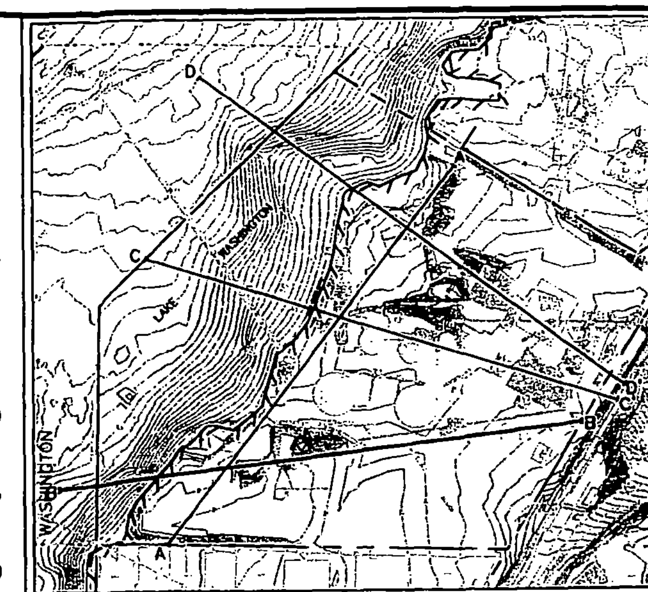
QUENDALL TERMINALS			GENERALIZED CROSS SECTION A-A' SHORELINE
JAGCO-02438-770			
DATE: 06/22/01	DRWN: N.S.	FILE: 2438g056	FIGURE 2-1





NOTE: DATUM = NAD 27 WA STATE PLANE NORTH

NOTES:

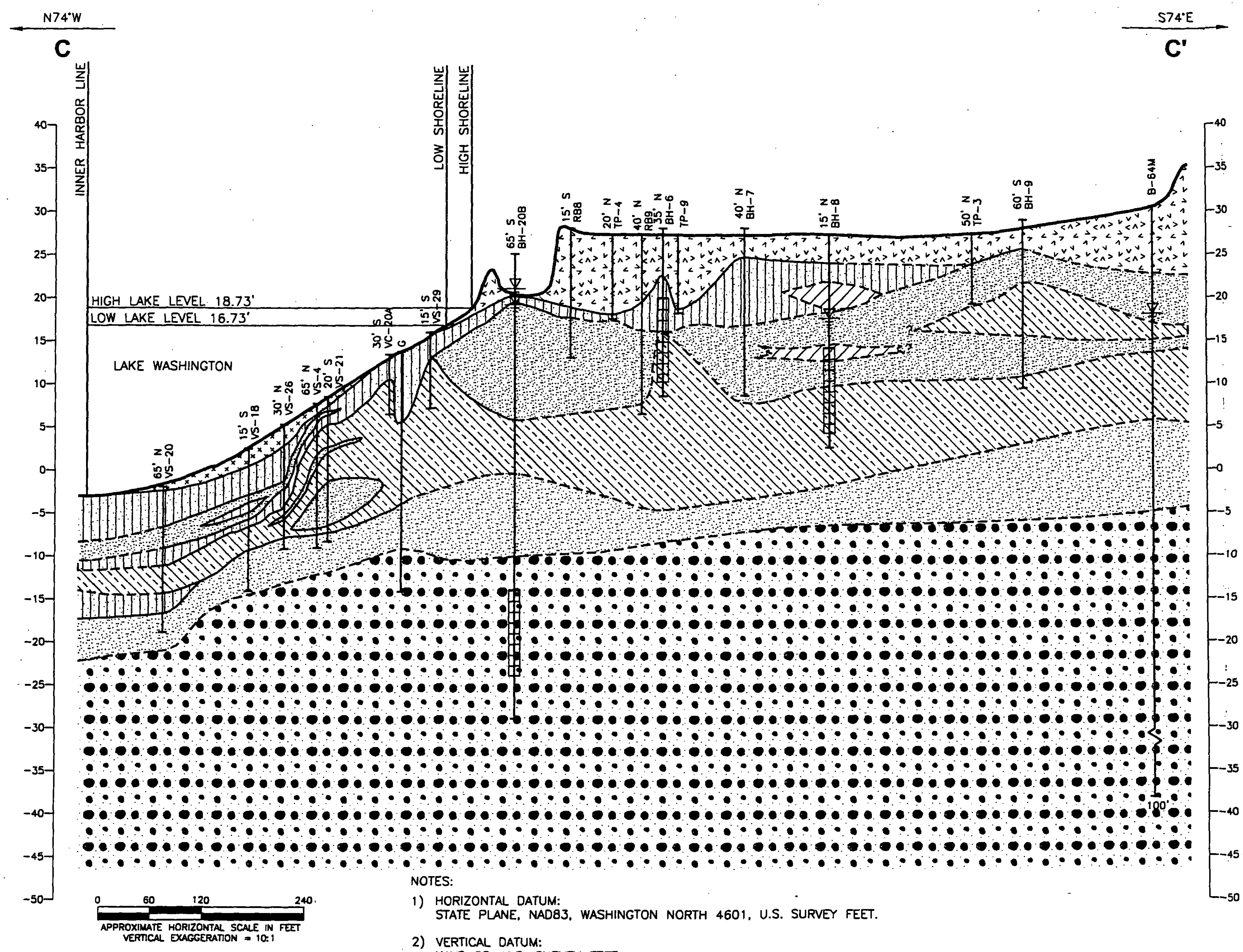
1) HORIZONTAL DATUM: STATE PLANE, NAD83, WASHINGTON NORTH 4601, U.S. SURVEY FEET.
2) VERTICAL DATUM: NAVD 88, U.S. SURVEY FEET
3) CONTACTS BETWEEN GEOLOGIC UNITS ARE INFERRED BASED ON INTERPOLATION BETWEEN BORING LOGS. ACTUAL SUBSURFACE CONDITIONS MAY VARY.
4) GROUNDWATER ELEVATIONS REPRESENT HIGH AND LOW GAUGING LEVELS FOR WELLS ONLY.

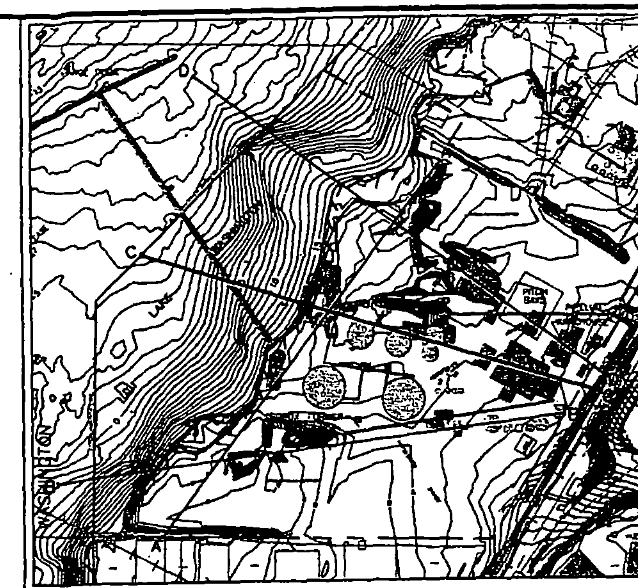
LEGEND

- FILL
- WOOD
- SILTY SAND
- CLAY or SANDY CLAY
- SAND OR GRAVELLY SAND
- PEAT
- GRAVEL OR SANDY GRAVEL
- WATER LEVEL
- SCREEN
- CONTACT W/ CERTAINTY
- UNCERTAIN CONTACT
- 35' SE RBB BORING LOCATION AND OFFSET

ThermoRetec

QUENDALL TERMINALS			GENERALIZED CROSS SECTION B-B' FORMER MAY CREEK
JAGCO-02438-770			
DATE: 06/25/01	DRWN: N.S.	FILE: 2438g059	FIGURE 2-2





NOTE: DATUM = NAD 27 WA STATE PLANE NORTH

LEGEND

- FILL
- WOOD
- SILTY SAND
- CLAY or SANDY CLAY
- SAND OR GRAVELLY SAND
- PEAT
- GRAVEL OR SANDY GRAVEL
- WATER LEVEL
- SCREEN
- CONTACT W/ CERTAINTY
- UNCERTAIN CONTACT
- 35' SE RB8 BORING LOCATION AND OFFSET

NOTES:

1) HORIZONTAL DATUM:
STATE PLANE, NAD83, WASHINGTON NORTH 4601, U.S. SURVEY FEET.

2) VERTICAL DATUM:
NAVD 88, U.S. SURVEY FEET

3) CONTACTS BETWEEN GEOLOGIC UNITS ARE INFERRED BASED ON INTERPOLATION BETWEEN BORING LOGS. ACTUAL SUBSURFACE CONDITIONS MAY VARY.

4) GROUNDWATER ELEVATIONS REPRESENT HIGH AND LOW GAUGING LEVELS FOR WELLS ONLY.

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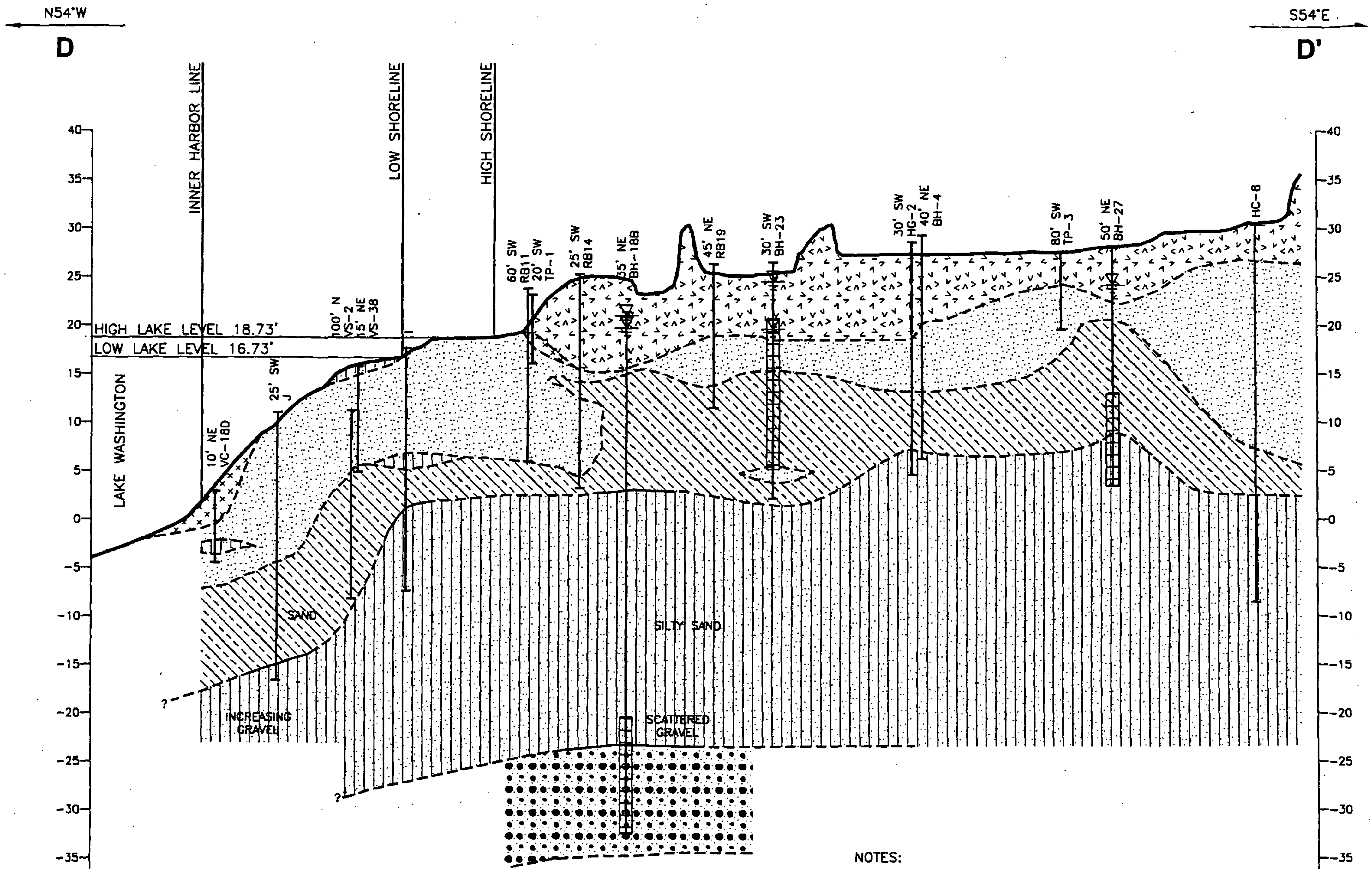
QUENDALL TERMINALS		
JAGCO-02438-770		
DATE: 06/25/01	DRWN: N.S.	FILE: 2438g058

GENERALIZED CROSS SECTION C-C'
STILL HOUSE, SOUTH SUMP, AND QUENDALL POND

FIGURE 2-3



-40

-45

-50

0 60 120 240

APPROXIMATE HORIZONTAL SCALE IN FEET
VERTICAL EXAGGERATION = 10:1

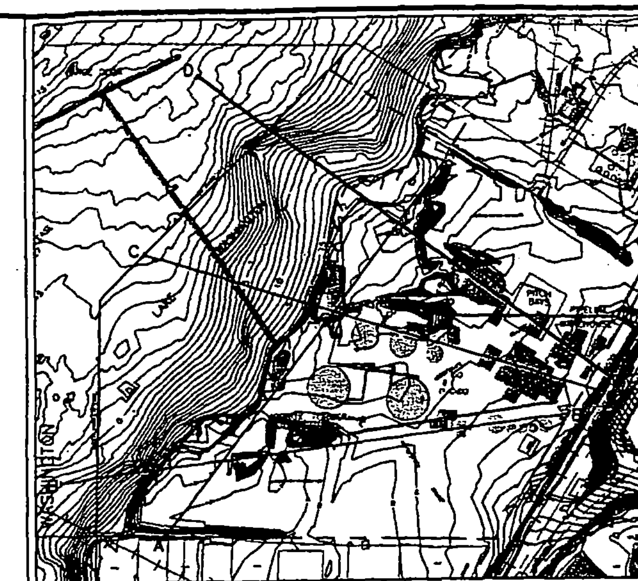
NOTES:

1) HORIZONTAL DATUM:
STATE PLANE, NAD83, WASHINGTON NORTH 4601, U.S. SURVEY FEET.

2) VERTICAL DATUM:
NAVD 88, U.S. SURVEY FEET

3) CONTACTS BETWEEN GEOLOGIC UNITS ARE INFERRED BASED ON INTERPOLATION BETWEEN BORING LOGS. ACTUAL SUBSURFACE CONDITIONS MAY VARY.

4) GROUNDWATER ELEVATIONS REPRESENT HIGH AND LOW GAUGING LEVELS FOR WELLS ONLY.



250 0 500

SCALE IN FEET

N

NOTE: DATUM = NAD 27 WA STATE PLANE NORTH

LEGEND

- FILL
- WOOD
- SILTY SAND
- CLAY or SANDY CLAY
- SAND OR GRAVELLY SAND
- PEAT
- GRAVEL OR SANDY GRAVEL
- WATER LEVEL
- SCREEN
- CONTACT W/ CERTAINTY
- UNCERTAIN CONTACT
- 35' SE RB8 BORING LOCATION AND OFFSET

ThermoRetec

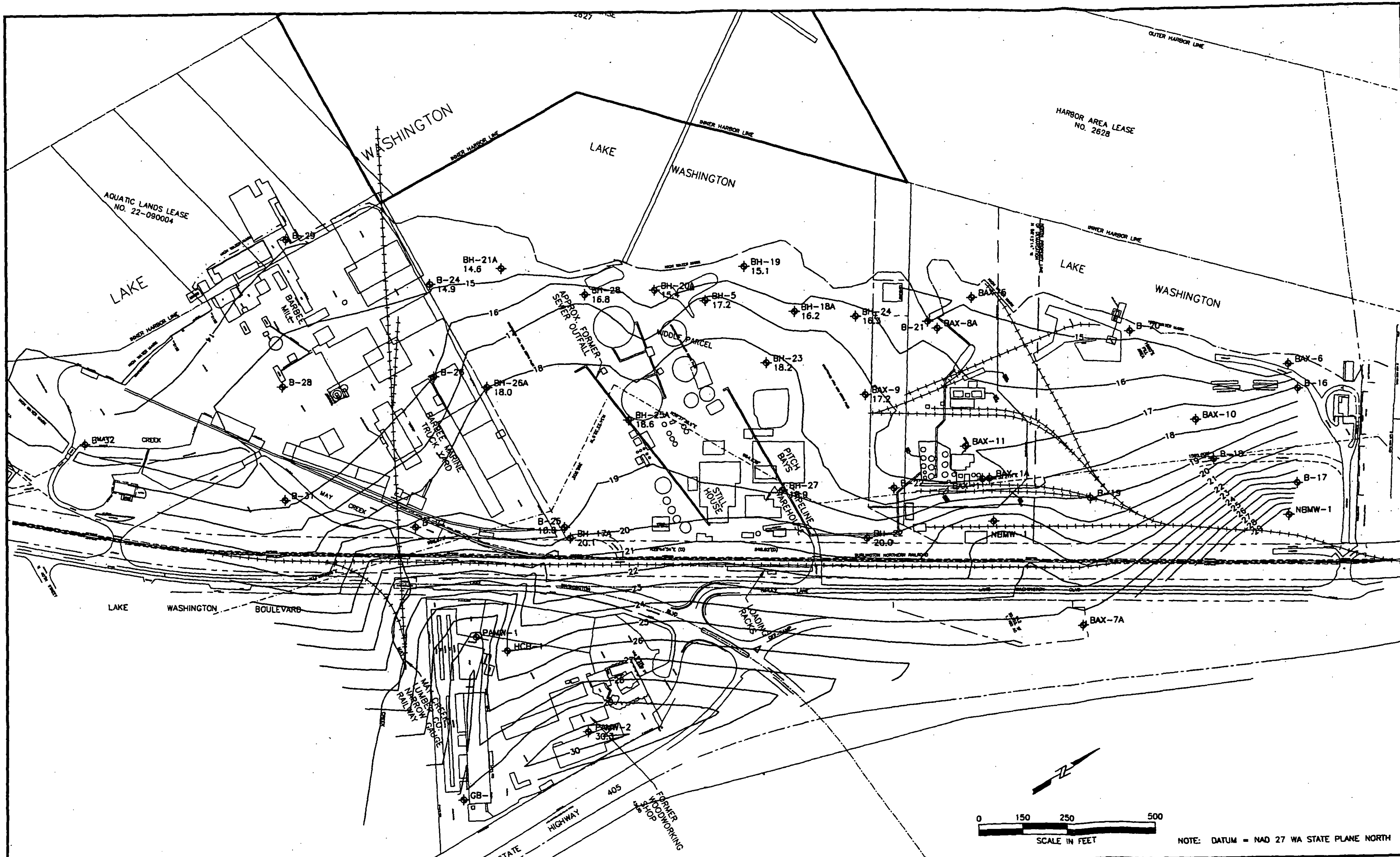
QUENDALL TERMINALS

JAGCO-02438-770

DATE: 06/22/01	DRWN: N.S.	FILE: 2438g057

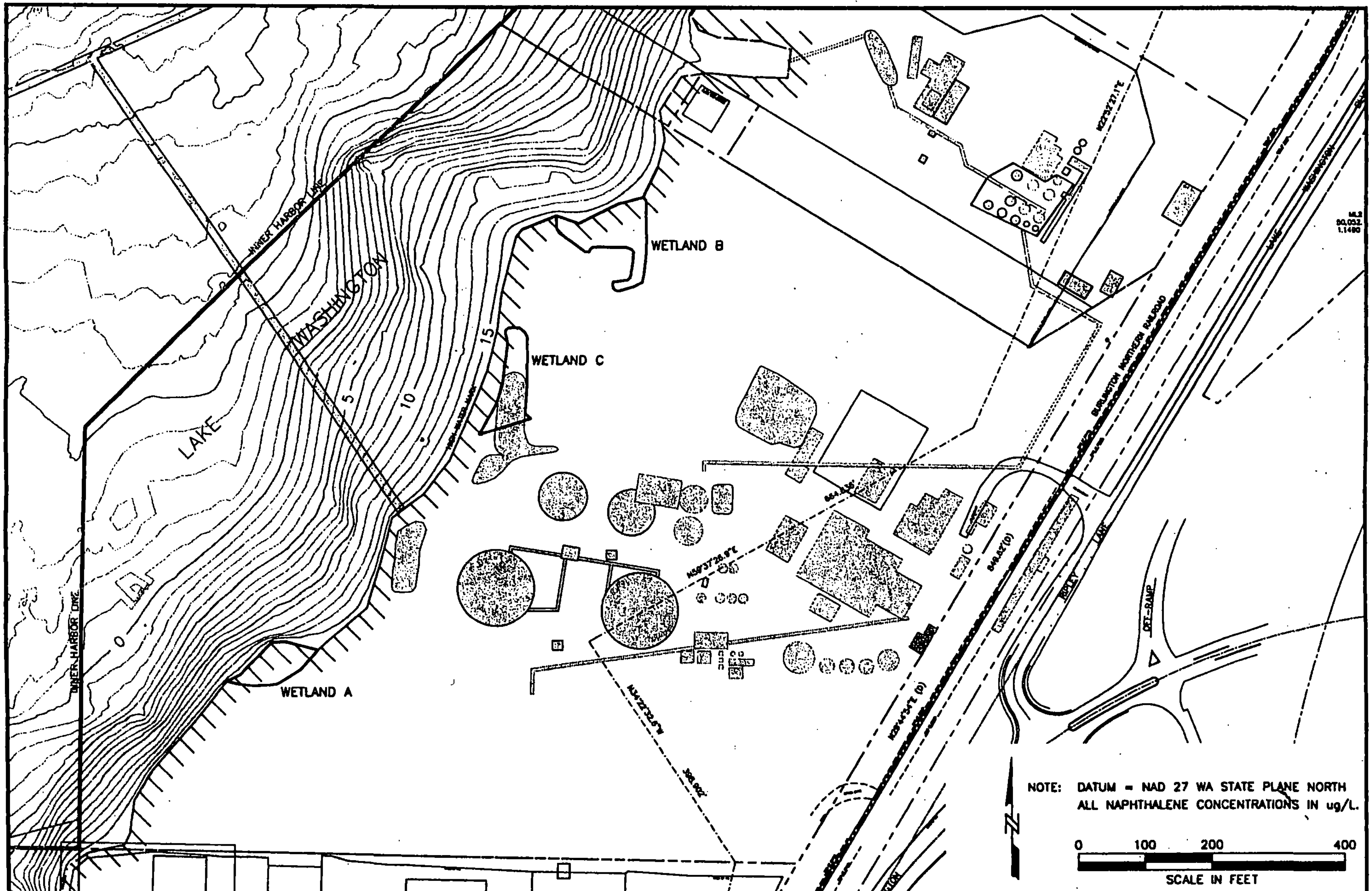
**GENERALIZED CROSS SECTION D-D'
NORTH SUMP**

FIGURE 2-4



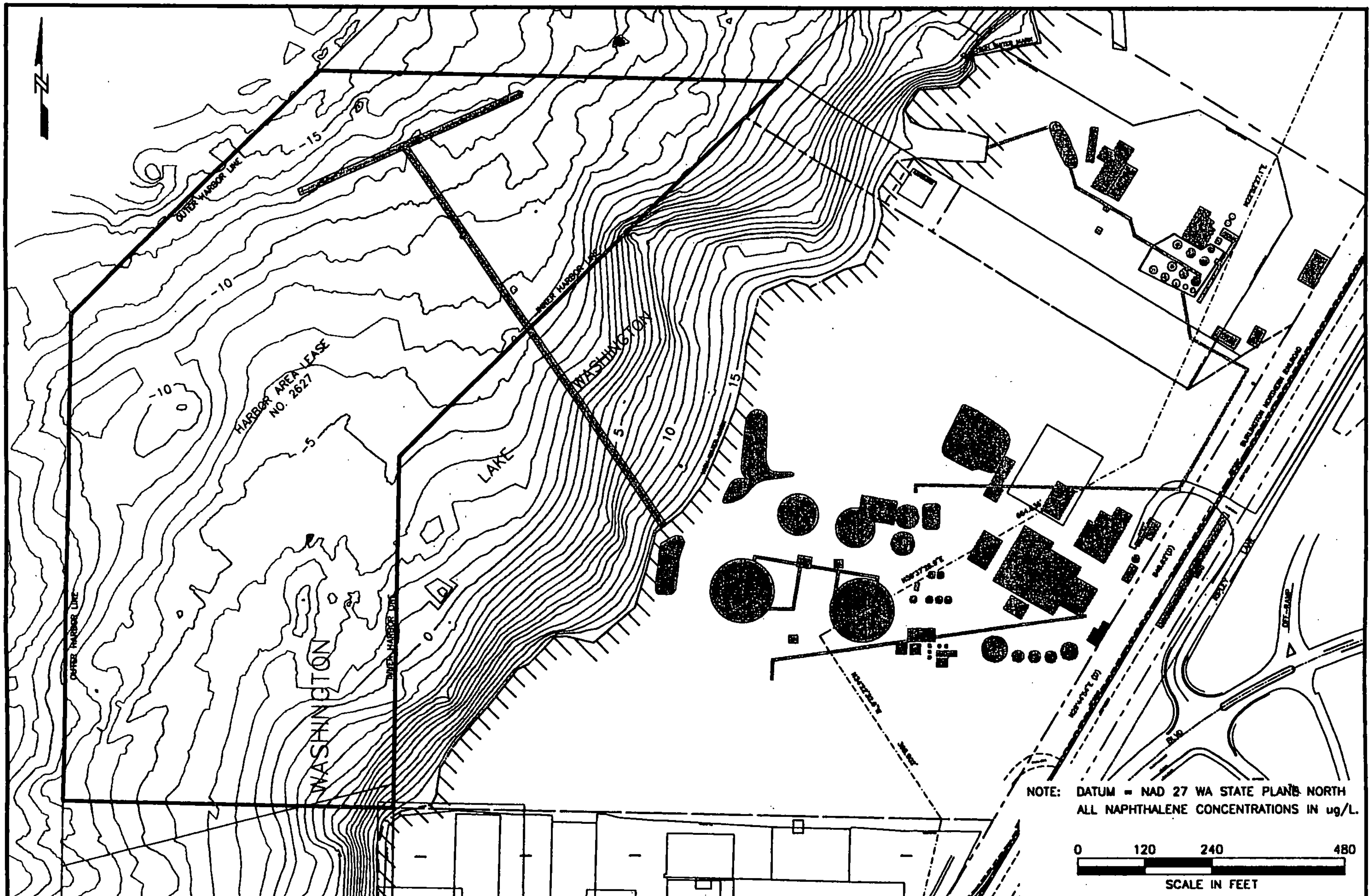
ThermoRetec

QUENDALL TERMINALS	AVERAGE SHALLOW WATER LEVELS
JAGCO-02438-770	FIGURE 2-5
DATE: 07/25/01 · DRWN: N.S. · FILE: 2438s392	



ThermoRetec

QUENDALL TERMINALS JAGCO-02438-770			WETLAND LOCATIONS
DATE: 07/20/01	DRWN: N.S.	FILE: 2438S385	FIGURE 2-6



ThermoRetec

QUENDALL TERMINALS	BATHYMETRIC CONTOURS
JAGCO-02438-770	
DATE: 07/20/01 · DRWN: N.S. · FILE: 2438S386	FIGURE 2-7

FOLDER NUMBER: **12.3.2**
DOCUMENT DATE: **3/27/02**

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 SIXTH AVENUE
SEATTLE, WA 98101

TARGET SHEET

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Document Information

Document ID #: 1259249
File #: **12.3.2**
Site Name: QUENDALL TERMINALS. QTXCF

FIG 3.1.
TOTAL PAH CONCENTRATIONS IN SOIL

FOLDER NUMBER: **12.3.2**
DOCUMENT DATE: **3/27/02**

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
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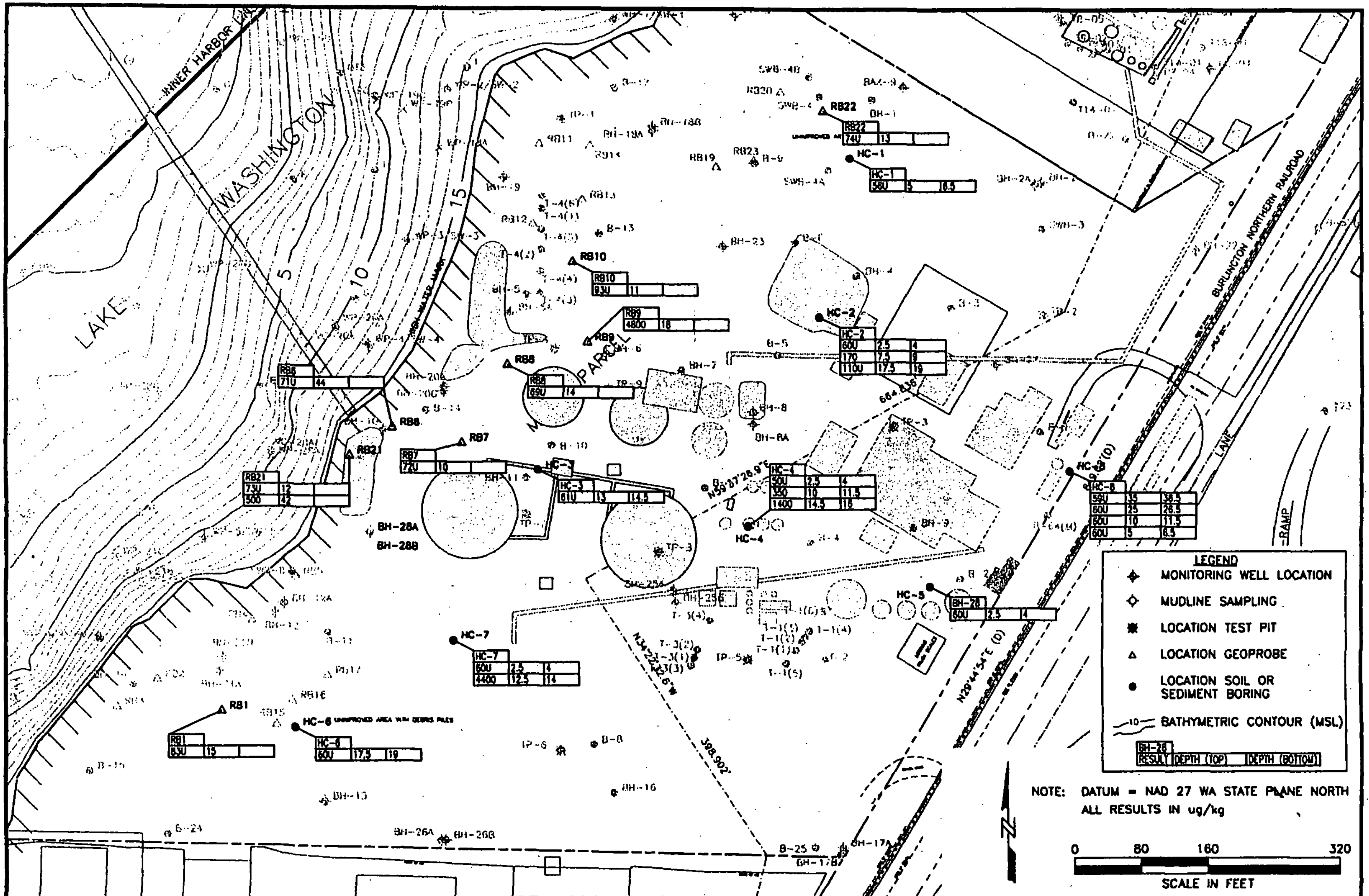
Document Information

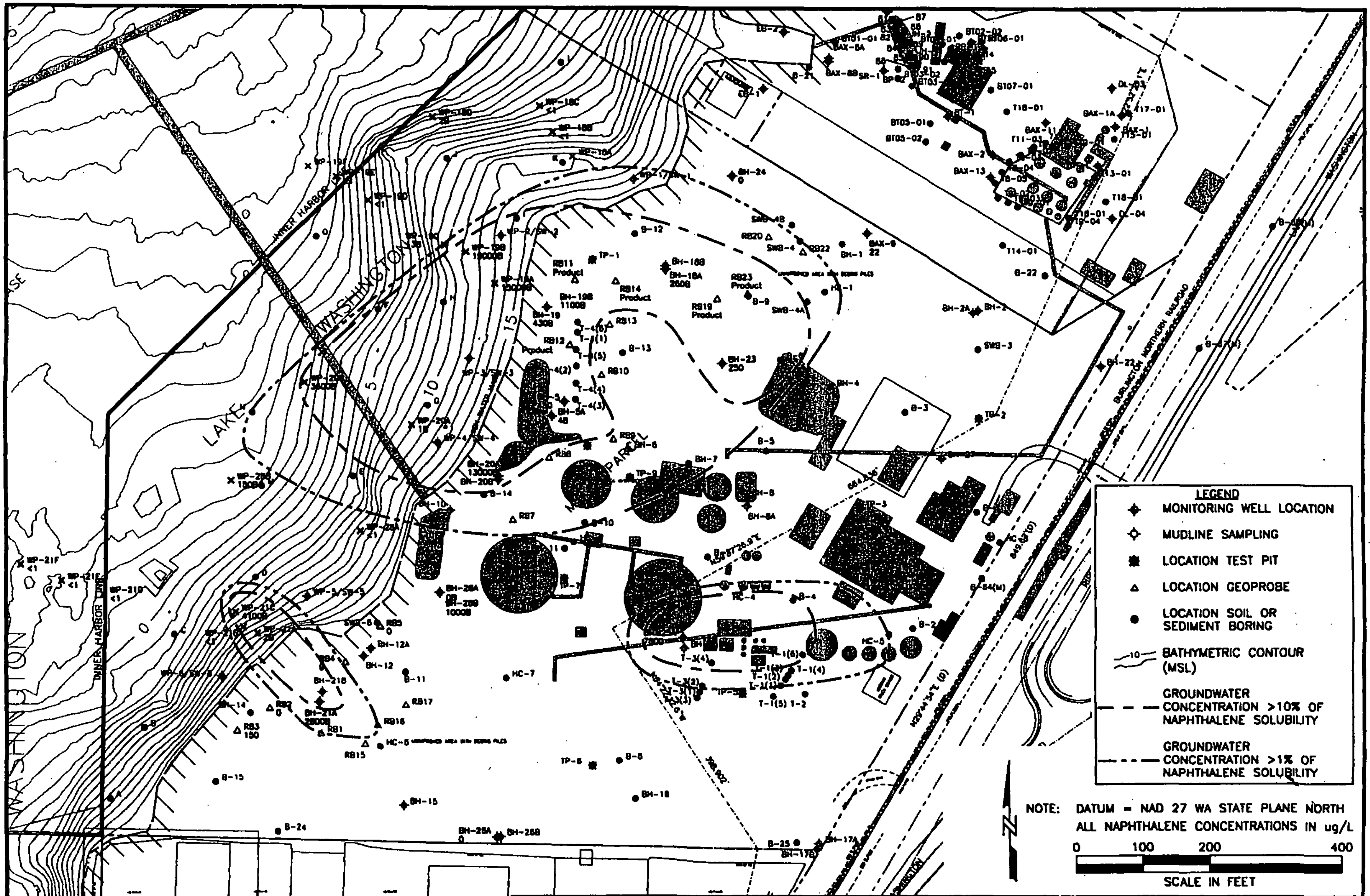
Document ID #: 1259249
File #: **12.3.2**
Site Name: QUENDALL TERMINALS QTXCF

FIG 3.2.
CPAH CONCENTRATIONS IN SOIL



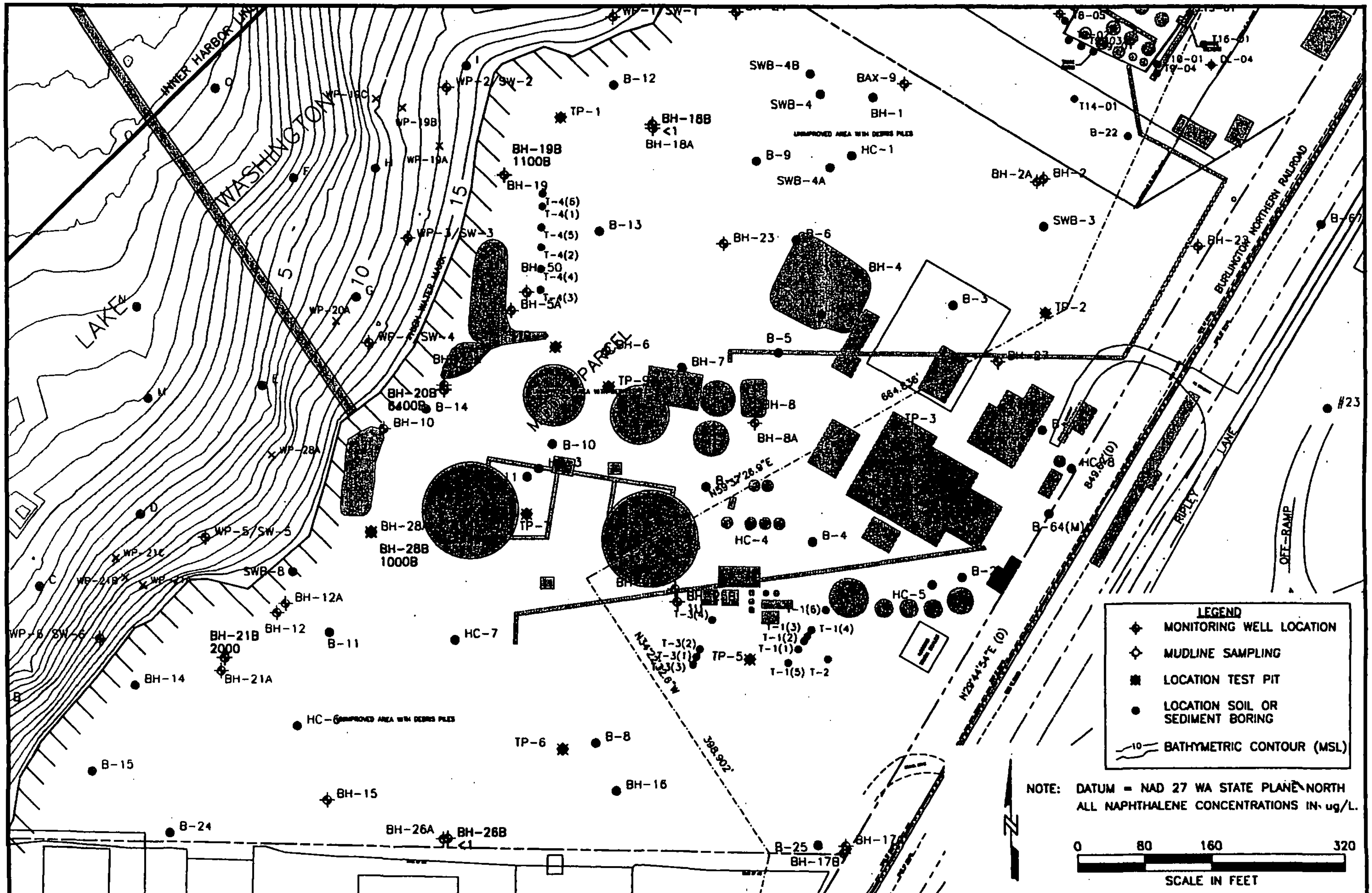
ThermoRetec

QUENDALL TERMINALS	BENZENE CONCENTRATIONS IN SOIL
JAGCO-02438-770	
DATE: 06/26/01 · DRWN: N.S. · FILE: 2438S372	FIGURE 3-3



ThermoRetec

QUENDALL TERMINALS			NAPHTHALENE SHALLOW GROUNDWATER CONCENTRATIONS JANUARY & APRIL 2001
JAGCO-02438-770			
DATE: 06/26/01	DRWN: N.S.	FILE: 2438S360	FIGURE 3-4



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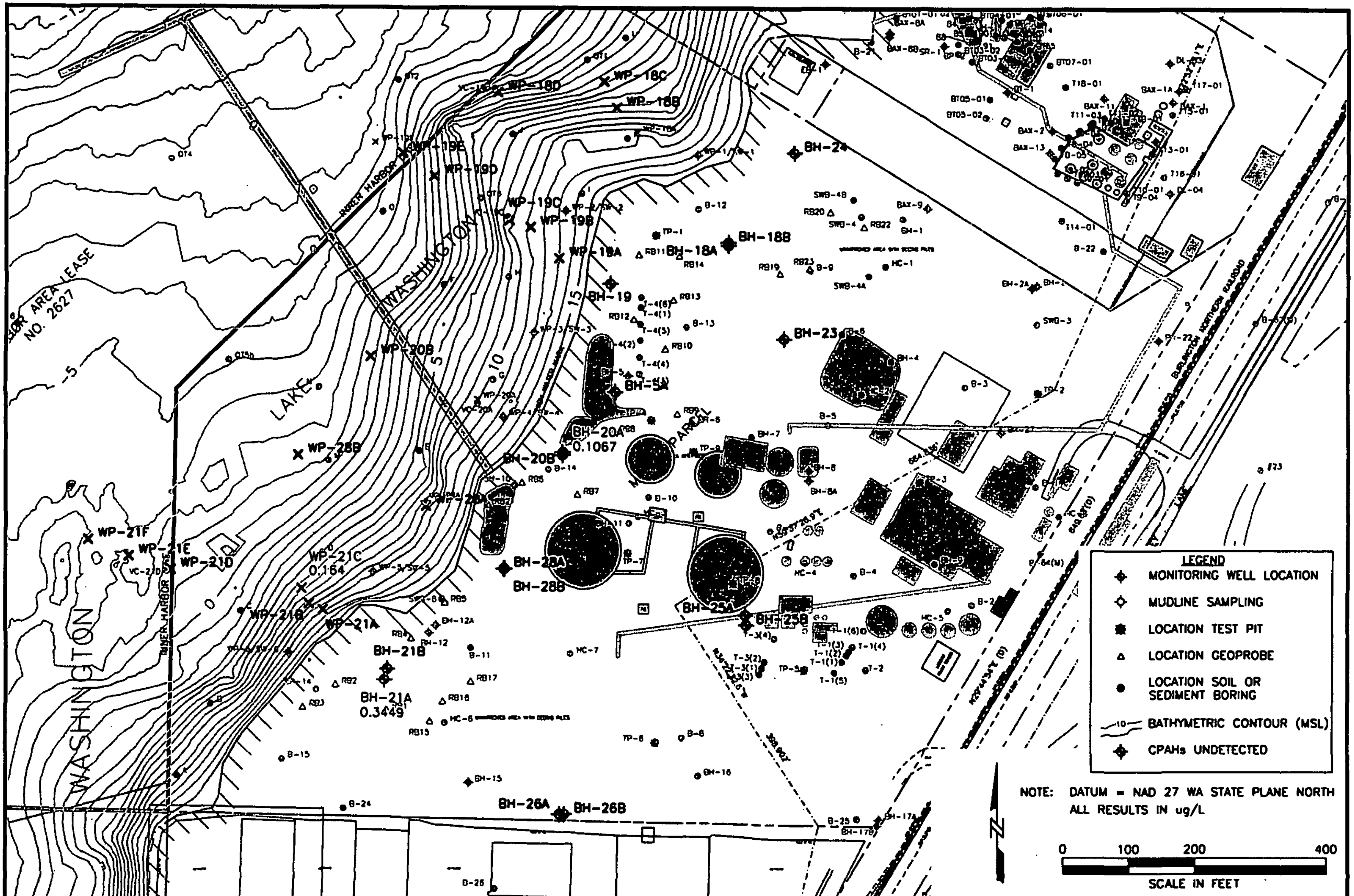
QUENDALL TERMINALS

JAGCO-02438-770

NAPHTHALENE DEEP GROUNDWATER CONCENTRATIONS JANUARY 2001

DATE: 06/26/01	DRWN: N.S.	FILE: 2438s374	FIGURE 3-5



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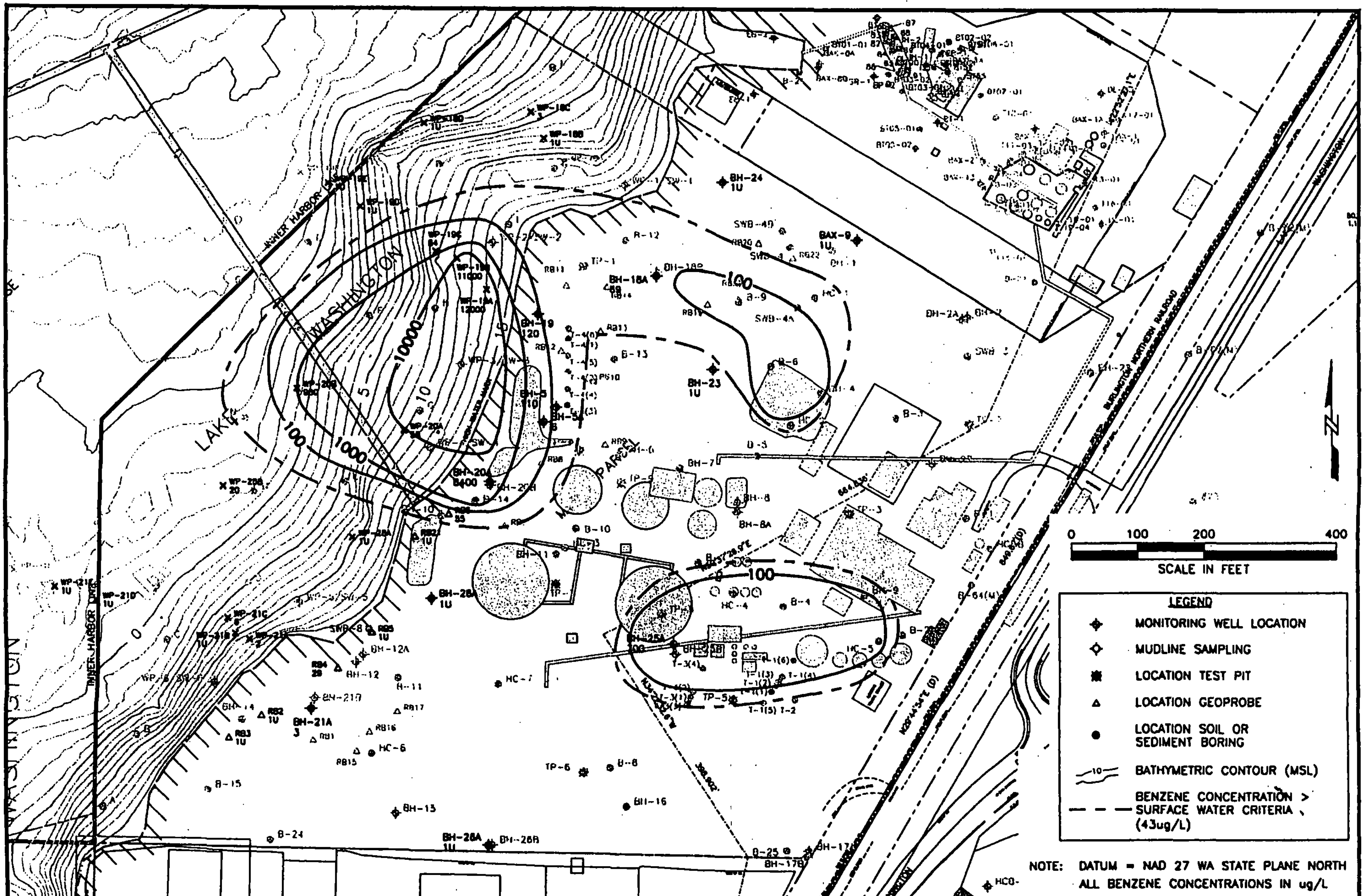
QUENDALL TERMINALS

JAGCO-02438-770

DATE: 06/26/01	DRWN: N.S.	FILE: 2438S371

TOTAL CPAH CONCENTRATIONS IN GROUNDWATER JANUARY 2001

FIGURE 3-6



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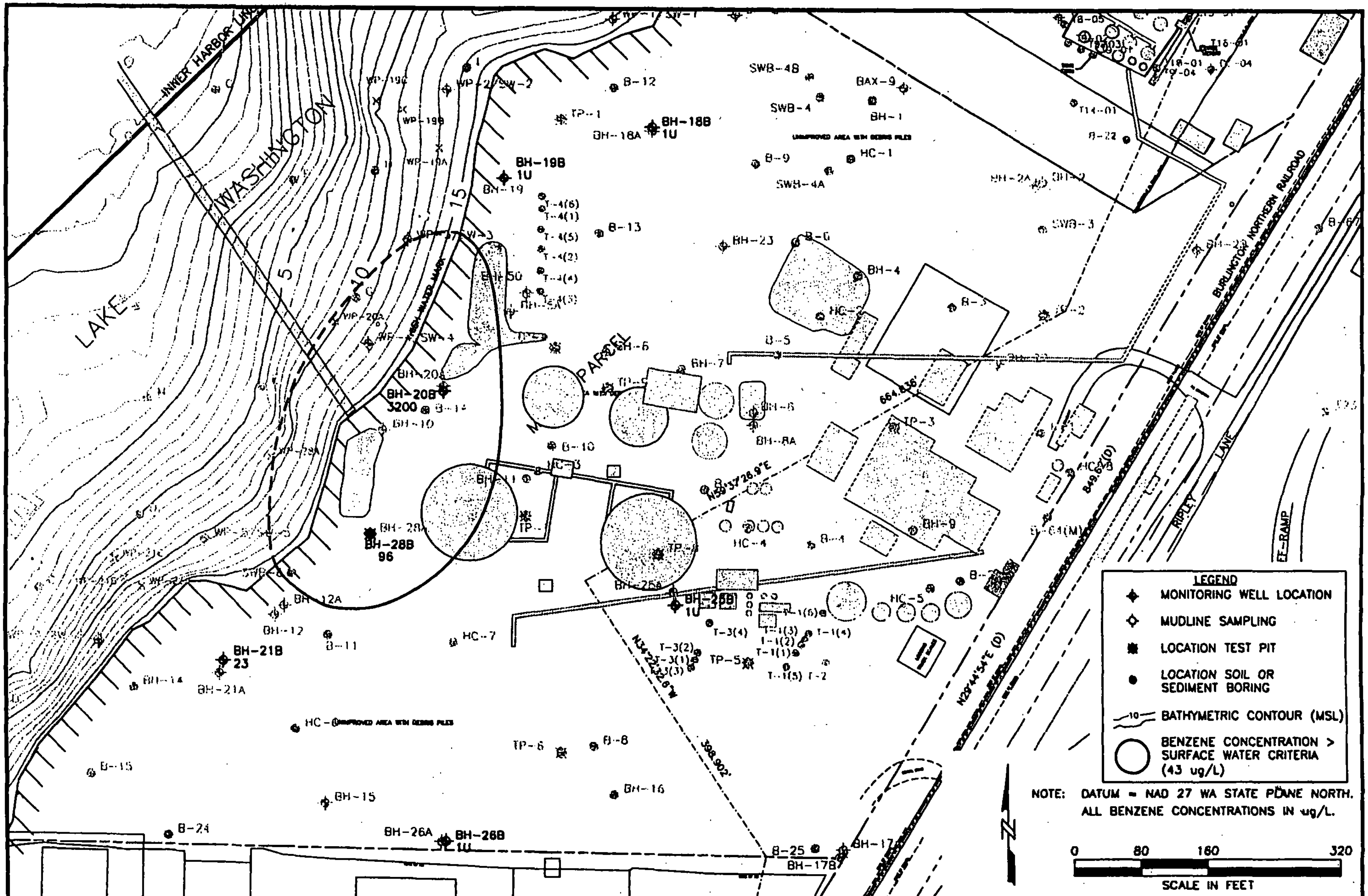
QUENDALL TERMINALS

JAGCO-02438-770

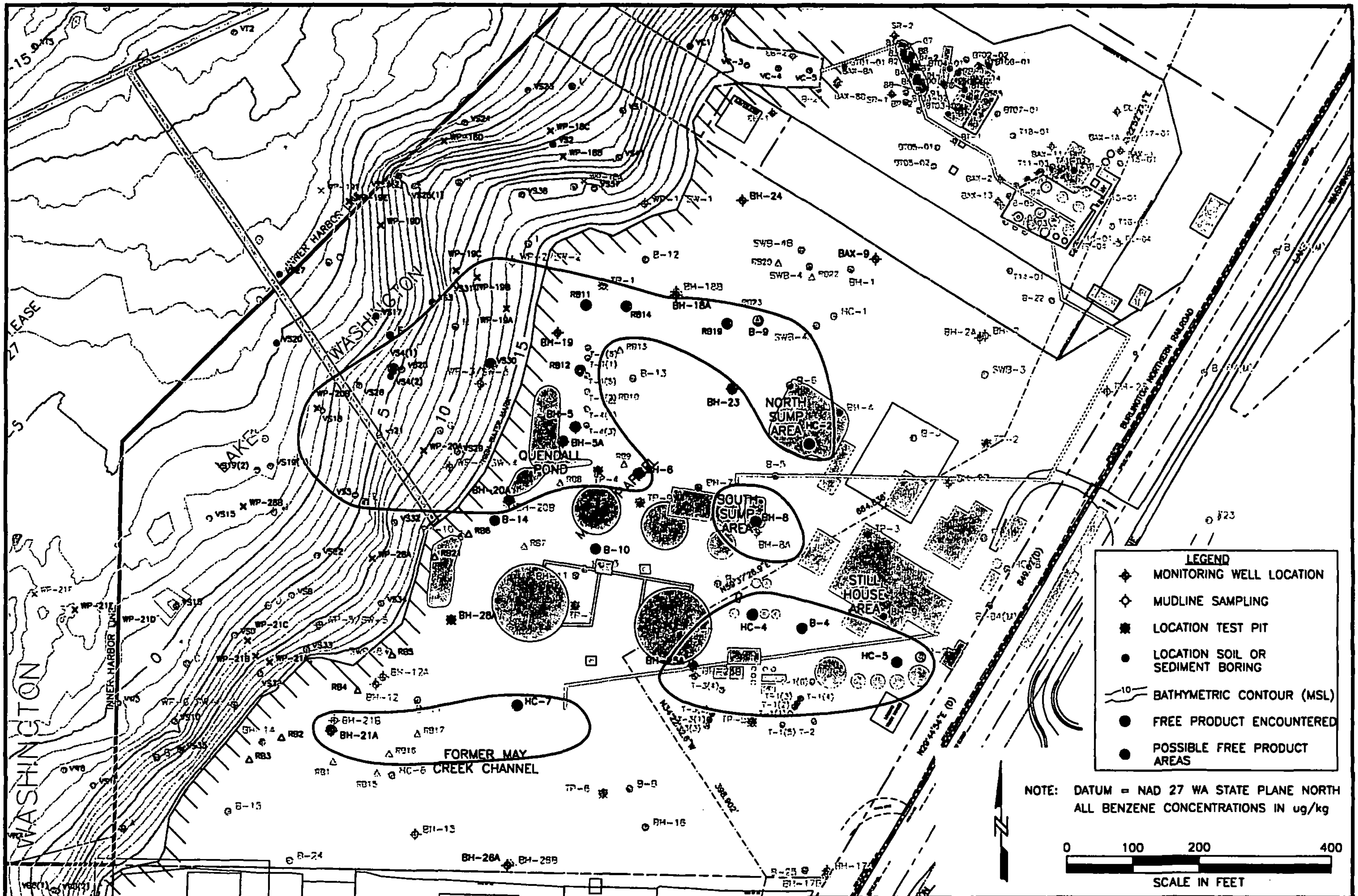
BENZENE SHALLOW GROUNDWATER CONCENTRATIONS JANUARY & APRIL 2001

DATE: 06/26/01	DRWN: N.S.	FILE: 2438s375	FIGURE 3-7



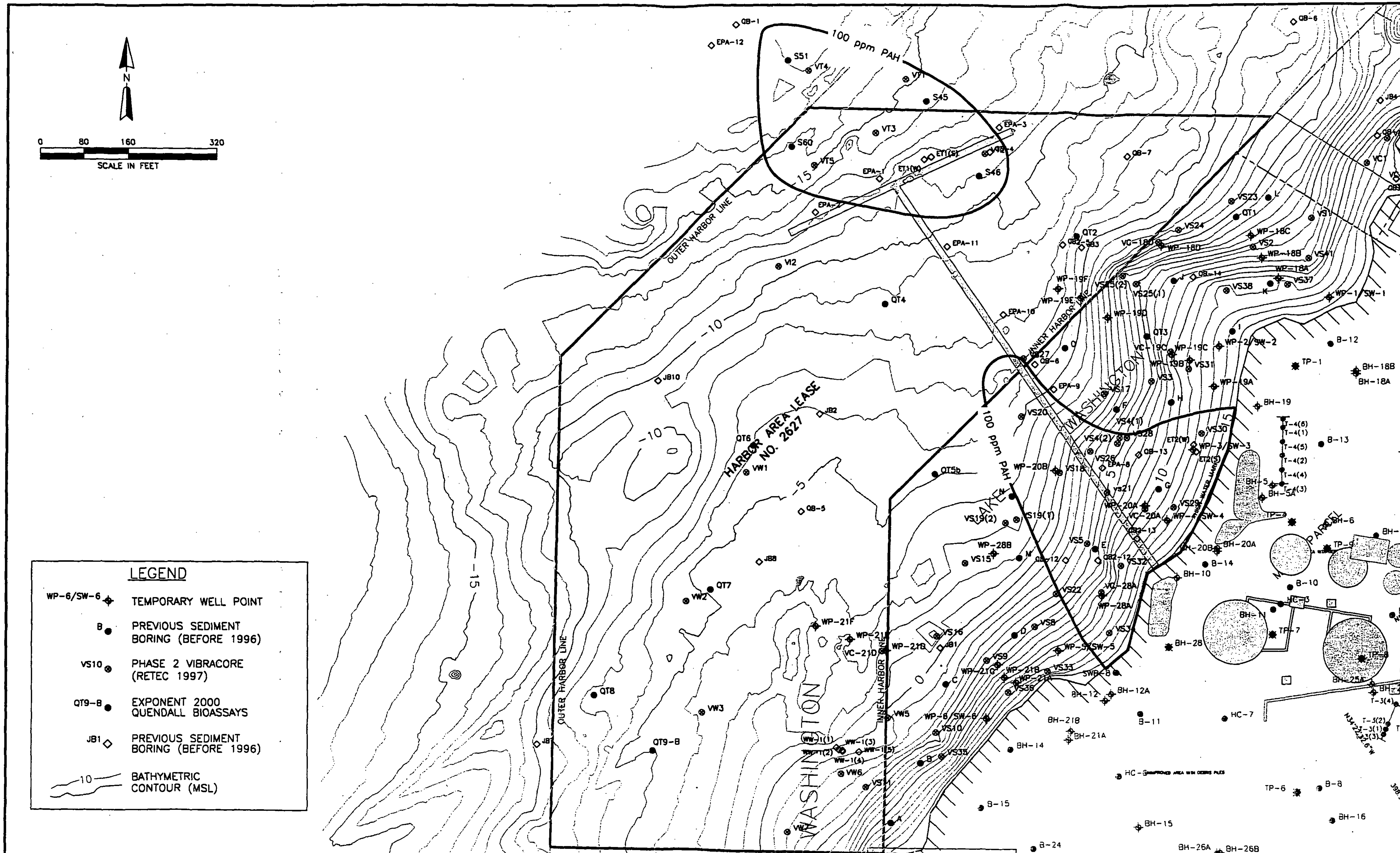
ThermoRetec

QUENDALL TERMINALS JAGCO-02438-770			BENZENE DEEP GROUNDWATER CONCENTRATIONS JANUARY 2001
DATE: 06/26/01	DRWN: N.S.	FILE: 2438a373	FIGURE 3-8



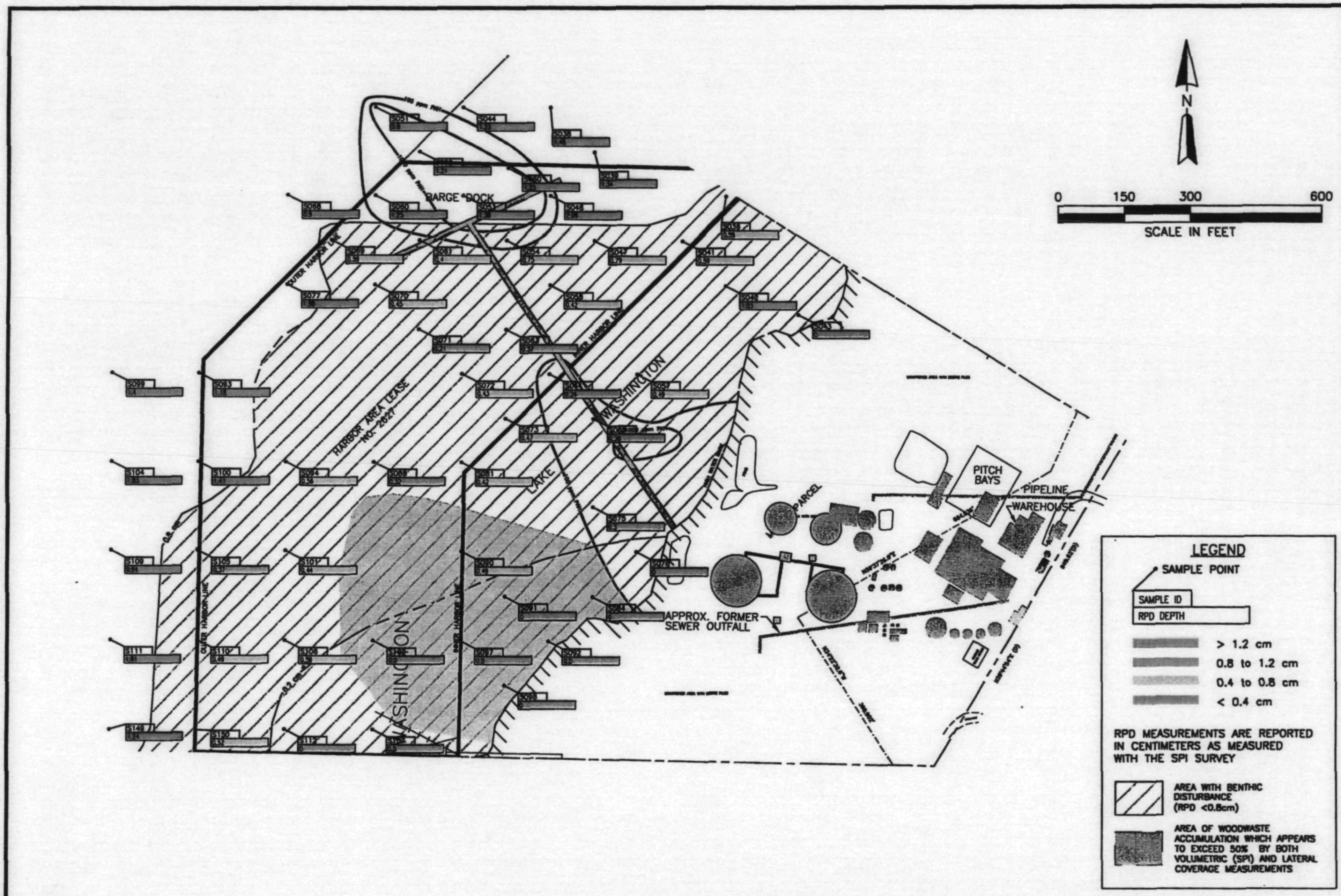
ThermoRetec

QUENDALL TERMINALS			DNAPL DISTRIBUTION
JAGCO-02438-770			
DATE: 07/18/01	DRWN: N.S.	FILE: 2438S382	FIGURE 3-9



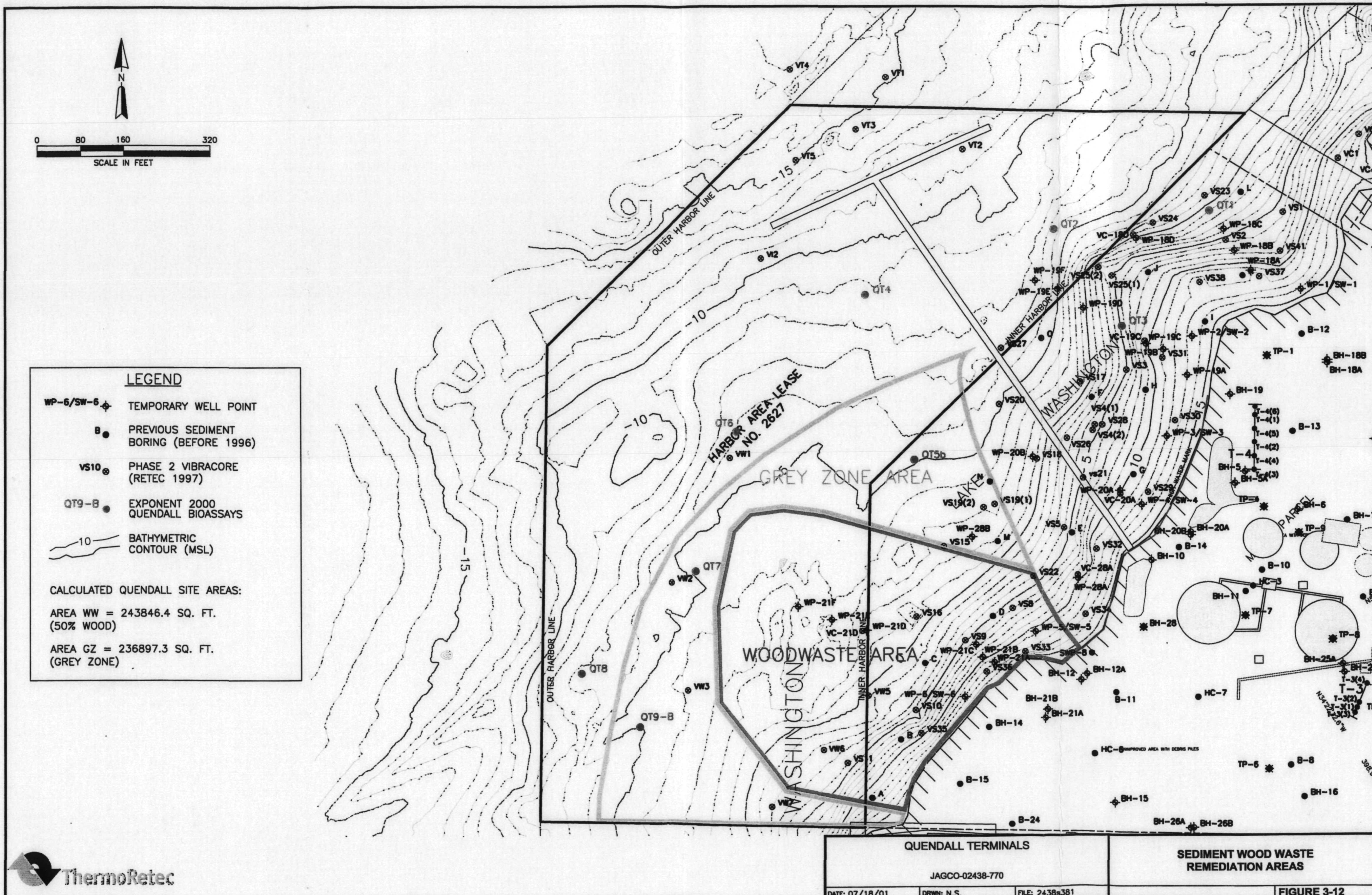
ThermoRetec

QUENDALL TERMINALS PROPERTY	TOTAL PAH IN SEDIMENT
JAGCO-02438-800	
DATE: 07/20/01 DRWN: N.S. FILE: 2438s390	FIGURE 3-10



ThermoRetec

QUENDALL TERMINALS	WOOD WASTE LOCATIONS
JAGCO-02438-770	
DATE: 07/18/01 — DRWN: N.S. — FILE: 2438s378	FIGURE 3-11



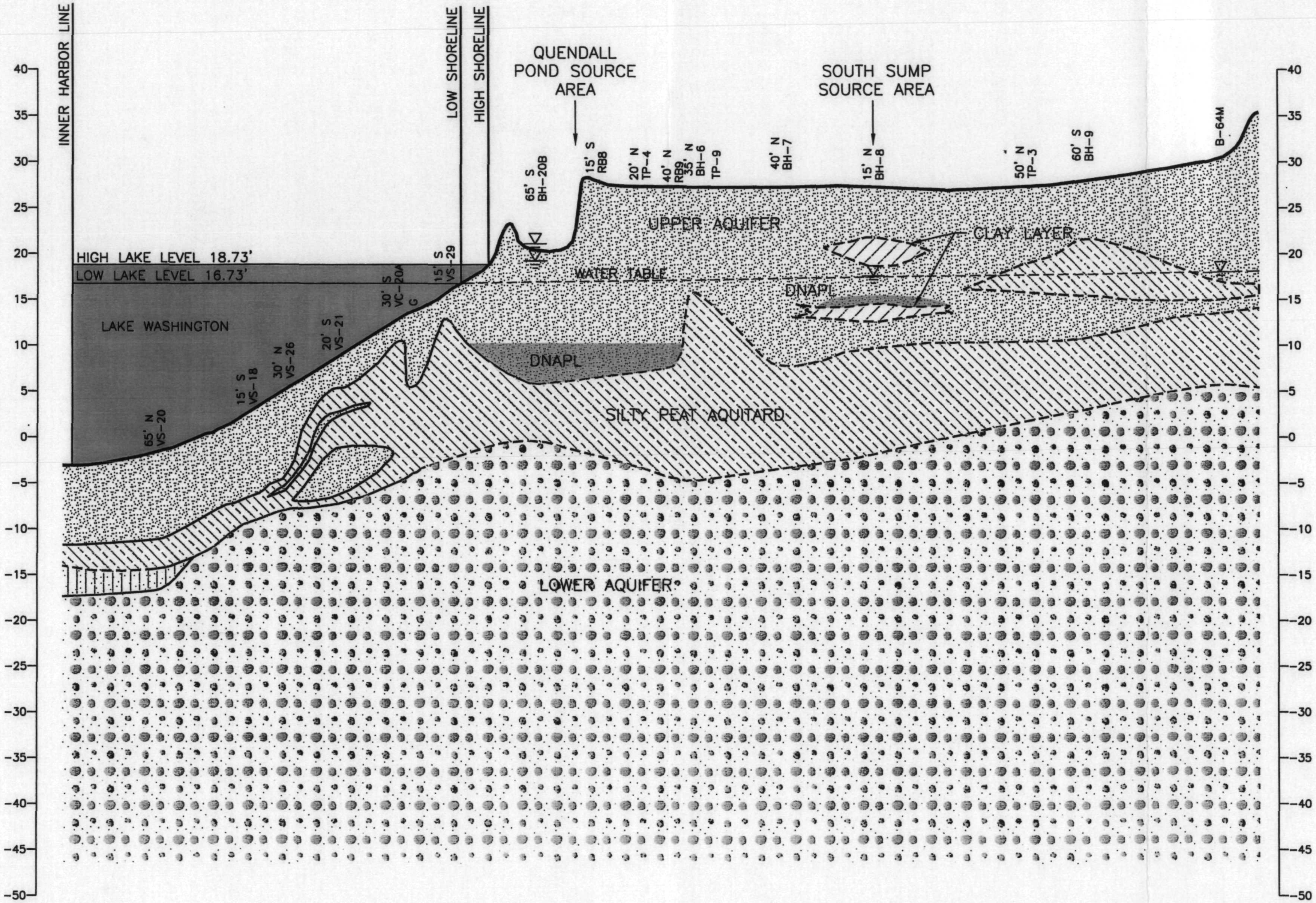
QUENDALL TERMINALS

JAGCO-02438-770

DATE: 07/18/01 | DRWN: N.S. | FILE: 2438s381

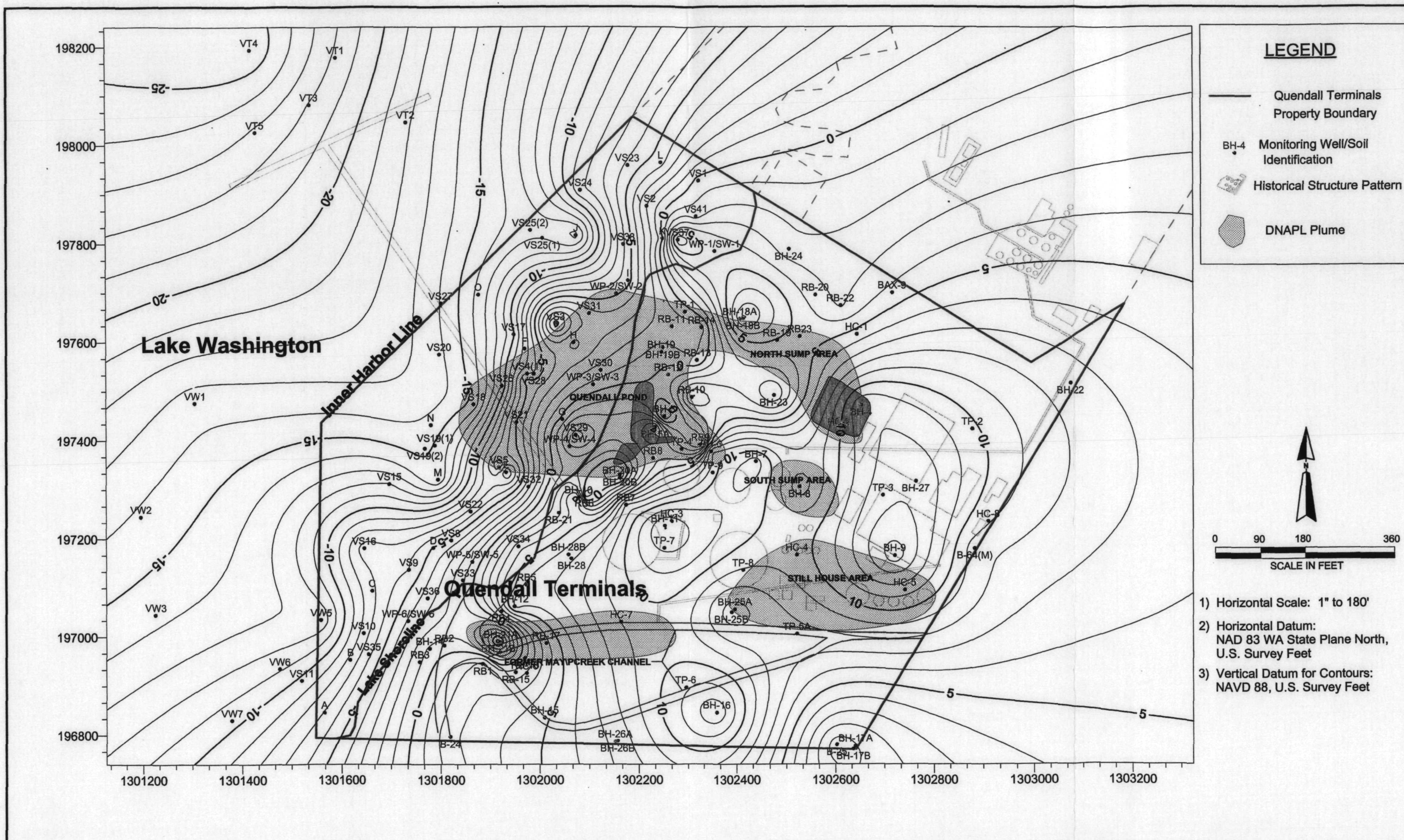
SEDIMENT WOOD WASTE REMEDIATION AREAS

FIGURE 3-12



ThermoRetec

QUENDALL TERMINALS	SITE CONCEPTUAL MODEL
JAGCO-02438-770	
DATE: 07/20/01 DRWN: N.S. FILE: 2438S387	FIGURE 3-13



RETEC

QUENDALL TERMINALS JAGCO-02438-770			CONTOURED SURFACE OF THE SILTY PEAT LAYER
DATE: 07/27/01	DRWN: A.W.	FILE: 2438S800	FIGURE 3-14